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G-824A CESIUM MAGNETOMETER

Operation Manual

P/N 27731-OM

Revision A8

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1.0 INTRODUCTION

Congratulations on your purchase or rental of one of the finest cesium vapor magnetometers ever produced. This manual will provide you with an understanding of alkali vapor magnetometer technology and will give you instructions for installing the system for airborne, land or marine use. It is not meant to be exhaustive for every case as there are many situations and applications in which magnetometers can be used. Please contact the factory if you have specific questions relating to your application.

The Geometrics G-824 magnetometer employs an optically pumped Cesium-vapor atomic magnetic resonance system that functions as the frequency control element in an oscillator circuit. The G-824 contains counter circuitry that internally converts the magnetometer's analog signal into a digital RS−232 output.

The frequency of the magnetometer electrical oscillator is known as the Larmor frequency and it varies directly with the ambient magnetic field at the sensor (white cylinder shown in Fig. 1). When this frequency is accurately measured it provides an extremely precise measurement of the earth's total magnetic field (better than 1 part in 10^8). The design of the sensor optical package uses a split-beam design which eliminates the need to optimize sensor orientation to obtain precise measurements.

As shown in Figure 1, the G-824 magnetometer consists of two interconnected modules: a sensor module and sensor driver module. The G-824 relies on counter circuitry that is internal to the sensor driver module using the Geometrics CM-321 SupremaC counter. Due to licensing concerns we do not offer the G-824 with analog Larmor output for external counting at this time. The system comes with a sensor, sensor driver module with counter, power/data cable (25 feet or 7.6 m), and an RS-232 output cable in a rugged shipping case. Optional accessories include MagLog logging software, power/data junction box, USB-Serial convertor, 110/220 VAC 50/60 Hz 28VDC power supply for lab use, birds, stingers and wing-tip sensor housing aircraft installation kits with internal orientation platforms.

A basic understanding of the physics employed in the G-824 and optically pumped resonance magnetometers in general is valuable for troubleshooting new installations and for achieving optimum results in the field. This information can be found in the Appendix A4 of this manual.

2.0 SYSTEM COMPONENTS

The basic system components of the G-824A consist of the sensor module, a sensor driver module, and an interconnect cable that is permanently attached to the sensor module and detachable from the sensor driver module. These components are identified in Figures 1 and 2. The weights, dimensions, and connector's specifications for these components and ancillary system components are listed below in Table 1.

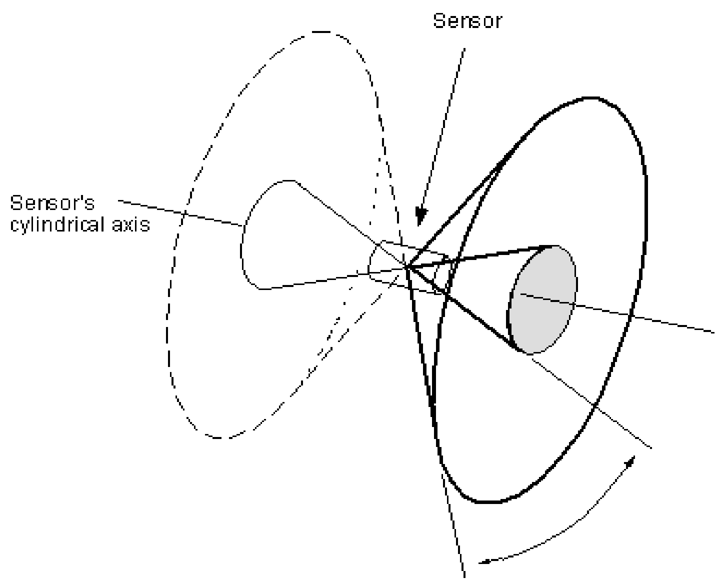
Figure 1 Sensor, sensor cable and Sensor Driver Module

Figure 2 G-824 System and Accessories

A multi-conductor cable connects the sensor driver module to the computer, power source, GPS, and optional junction box. The cable carries power and GPS 1PPS signal to the module and digital data from the module. The multi-conductor cable may be as long as 200ft (61m) for interconnection with a computer or optional power/data junction box (e.g., Geometrics Cable P/N 27748-01 for use without power/data junction box or Geometrics Cable P/N 27746-01 for use with optional power/data junction box)

3.0 PERFORMANCE

Geometrics G-824A magnetometer produces an RS-232 digital data transmission based on the Cesium Larmor frequency of 3.498572 Hz per nT (nanoTesla). Nano-Tesla refers to the magnetic field strength also known as one gamma or 10^{-5} gauss. At the earth's surface in a nominal 50,000 nT field the Larmor frequency is about 175 kHz which is converted using a proprietary counting system in the internal CM-321 SupremaC counter. The output of the G-824A is an RS-232 transmission at up to 1000 samples per second.



Sensor Active Zone extends from 15º to 75º referenced to the cylindrical axis (for both hemispheres.)

Figure 3 Active zone for the cesium-vapor sensor.

The G-824A is primarily intended for use in airborne and land/ base station applications, and operates over the earth's magnetic field range of 17,000 to 100,000nT. Absolute accuracy (as compared to an international standard) is rated at ± 2nT over the earth's magnetic field range independent of orientation and does not drift with time. The accuracy of the internal counter's time base is extremely high and with oversampling techniques used can give noise levels in the range of 0.4pT/√Hz RMS or 10 times better than the CM-201 counter in the G-823 and G-882. Error due to orientation of the G-824A does not exceed ±0.3nT or 0.6 nT peak-to-peak (p-p) in spin and tumble throughout the active zones shown in Figure 3. Environmental conditions for proper operation are -35 to +50°C (-31 to +122° F), humidity to 99 percent (non-condensing), and an altitude range of 0 to 30,000 feet.

Like all magnetometers, performance of the G-824A is primarily dependent upon the counting circuitry employed and the quality of the installation procedures. Compensation and/or noise reduction techniques must normally be used to minimize the magnetic effect of the platform (aircraft, UAV or AUV) and its motion. Navigational and positional errors, radiated electromagnetic noise and heading errors from the aircraft's induced and remnant magnetic fields are typically the major contributors to noise in the survey results.

4.0 INSTALLATION

The particular installation requirements for each system component must be met in order to obtain the best performance from the system. It is important to remember that the sensor driver circuit receives a signal from the sensor whose amplitude is normally one

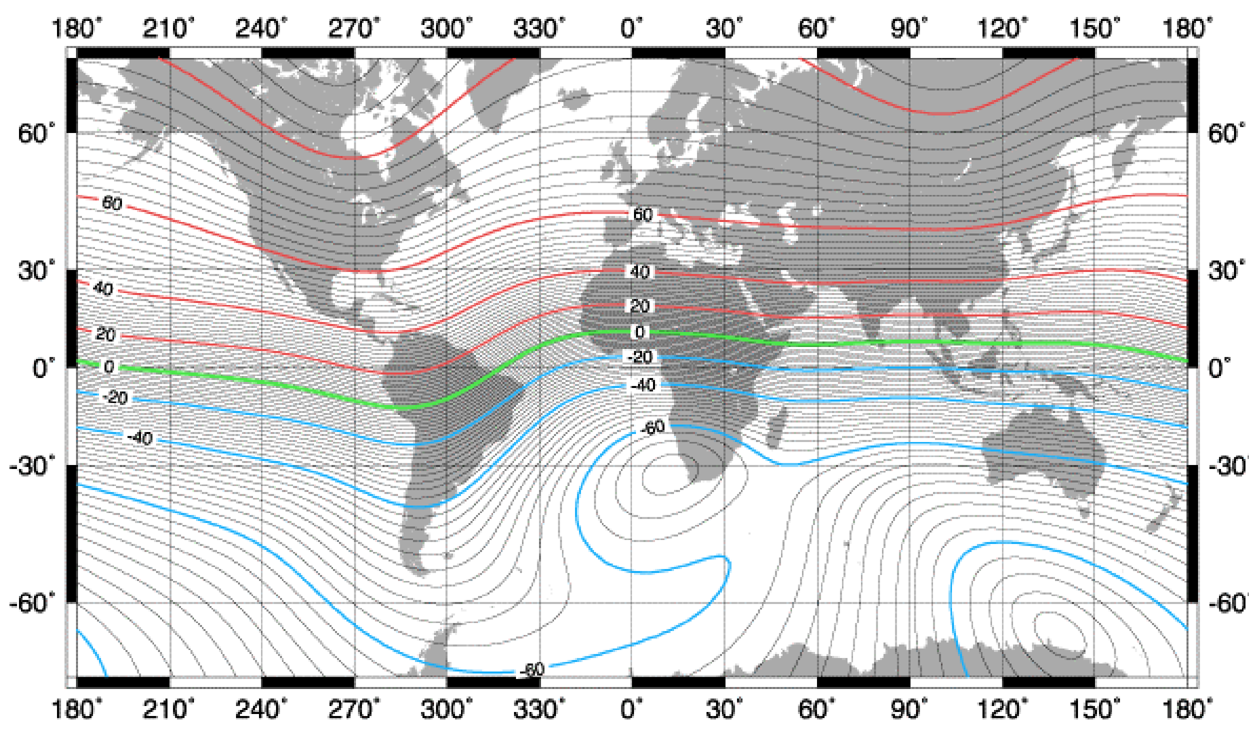


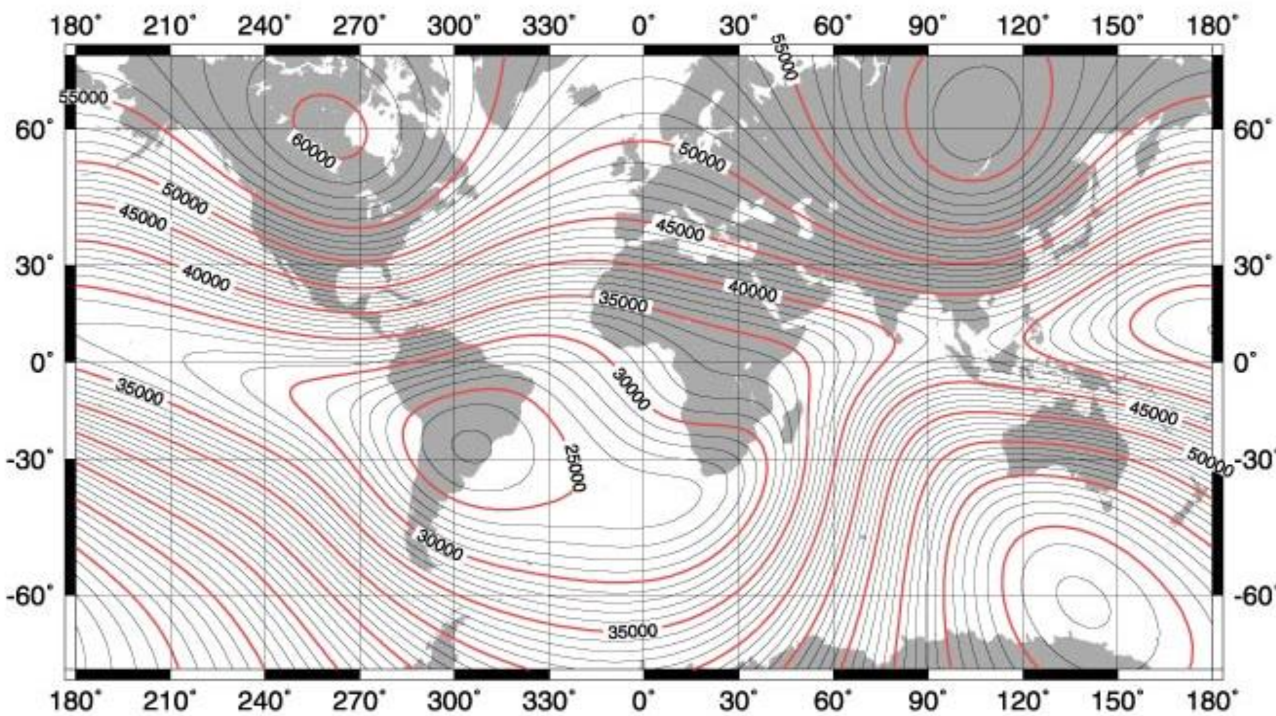
Figure 4 Showing inclination of earth's magnetic field

milli-volt as it delivers both heater and lamp oscillator power to the sensor. Anything that increases the cross-talk between the power and signal circuits or introduces noise into the power circuit can degrade the sensor output signal and affect system performance.

4.1 Sensor orientation

Although the G-824A measures the total intensity of the earth's magnetic field, magnetic fields in general are vector fields. The total field is the sum of the three components as projected onto the earth's field vector which is roughly vertical at the poles and horizontal at the magnetic equator. At any point the field is defined by its magnitude and direction. Unless the sensor is very near highly magnetic objects, the local magnetic field will be almost entirely due to the earth's magnetic field. In order for the G-824A to accurately measure the local magnetic field magnitude, it must be properly oriented relative to the local magnetic field direction.

The sensor head must be oriented so that the local field flux vector impinges at an angle of from 15º to 75º to the cylindrical axis of the sensor, for all platform attitudes encountered during survey. Alignments that produce a field/axis angle less than 15º place the magnetic field within the sensor's "polar dead zone". Similarly, alignments that produce a field/axis angle greater than 75º place the magnetic field within the sensor's



Epoch 2000, 1000 nT contour interval.

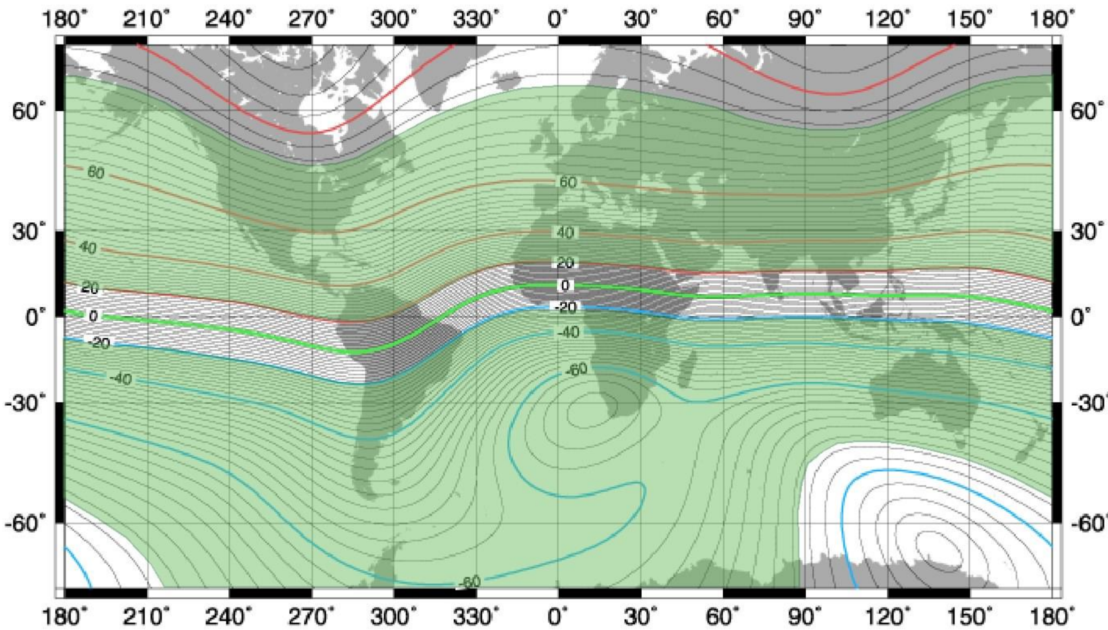
Figure 5 Magnetic field intensity at the Earth's surface.

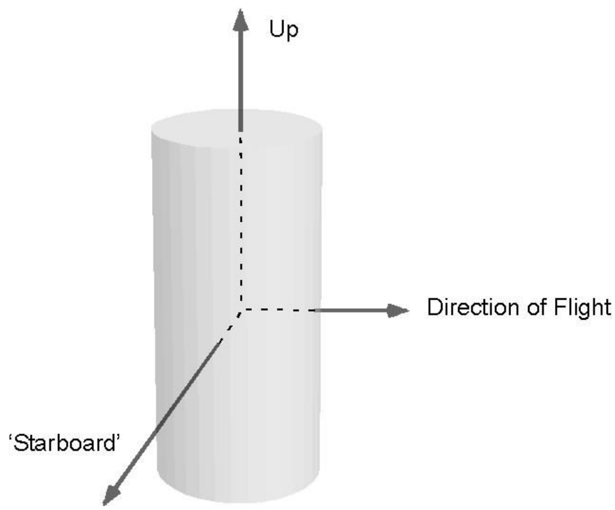
"equatorial dead zone". The sensor will not produce usable data when the angle between the earth's field and the cylindrical axis falls within one of these two zones. So, in latitudes where the inclination of the earth's field vector is 45º, vertical orientation of the sensor's axis will allow operation in all flight attitudes and directions. In equatorial regions it may be necessary to orient the sensor at a 45º (for E-W flight direction) or horizontally and at an angle to the flight path (NW-SE, NE-SW). In polar regions the sensor may be mounted with its major axis tilted at 45º in any direction to obtain the desired angle for omnidirectional survey.

The maps in Figures 4 and 5 may be used to determine the inclination and total intensity of the Earth's magnetic field in the intended area of survey. This inclination information should be used to adjust the sensor orientation for the best performance in the survey area. The intensity information may be used as a check of the system operation.

Geometrics also offers a program called CSAZ which is available for download from our website (Magnetometers, Downloads, Software) and on the supplied Magnetometer CD. CSAZ calculates the proper sensor orientation for all positions and survey directions and shows the optimum sensor orientation. It also calculates the total field, inclination (tilt or dip) and declination (offset between magnetic north and geographic north) for every latitude and longitude position on the earth's surface. Go to www.geometrics.com for more information.

In regard to sensor orientation, the Earth's surface can be divided into three zones based on magnetic field inclination: mid-latitude, equatorial, and polar. Within each of these zones there is a particular sensor orientation that will yield optimum signal strength over the entire zone. These regions and the corresponding sensor orientations recommended for each region are shown in Figures 6 through 8.

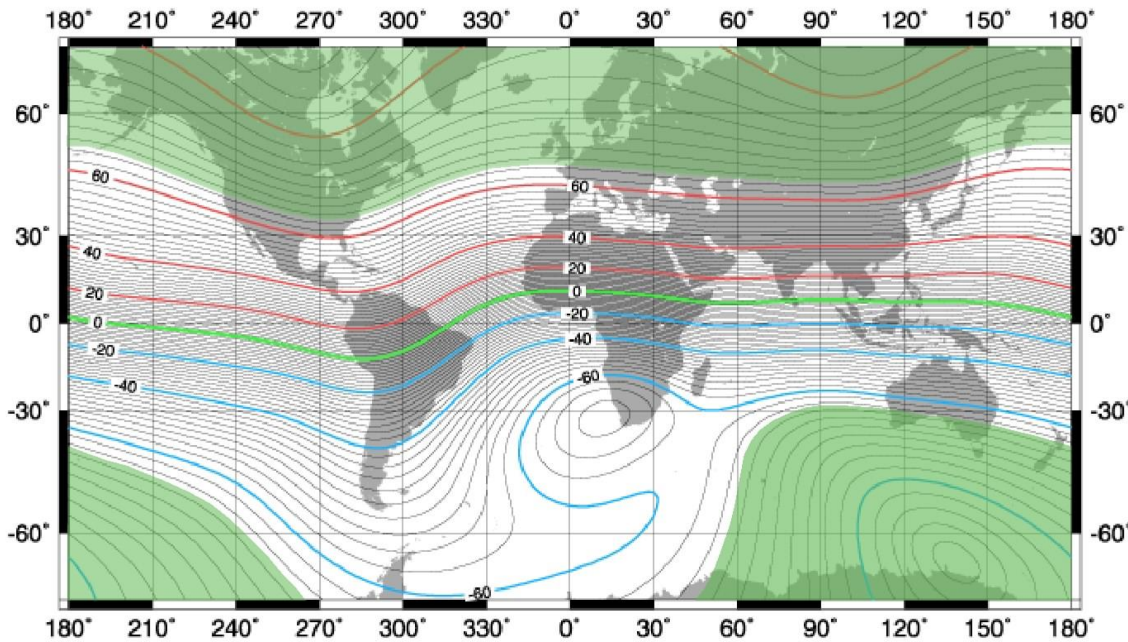


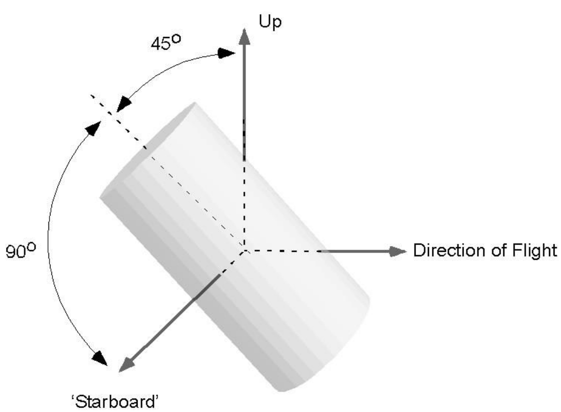


The diagram to the left shows the recommended sensor orientation for operation in mid-latitudes. This zone is shown as the shaded regions above and includes those areas where the absolute inclination of the Earth's magnetic field is greater or equal to 20º and less than or equal to 75º. There are no restrictions on the direction of travel when using this sensor orientation.

Figure 6 Mid-latitude zone.

Note that the orientation zones show in Figures 6 through 8 overlap one another by 10º of magnetic inclination. In these regions of overlap either of the recommend orientations may be used. Also, note that in the equatorial region there are two different recommended sensor orientations. In this region the magnetic field is nearly horizontal and there may be some restrictions on the direction of flight. Choosing one of the two recommended orientations will allow you to choose flight directions most suitable for your survey area.





The diagram to the left shows the recommended sensor orientation for operation in polar latitudes. This zone is shown as the shaded regions above and includes those areas where the absolute inclination of the Earth's magnetic field is greater or equal to 65º. There are no restrictions on the direction of travel when using this sensor orientation.

Figure 7 Polar Zone sensor orientation

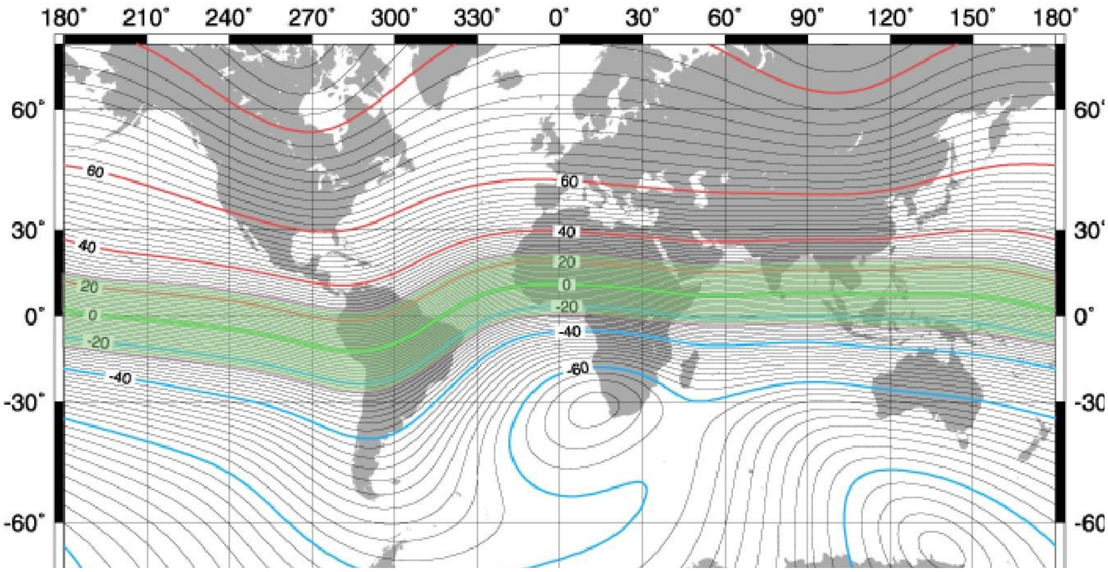
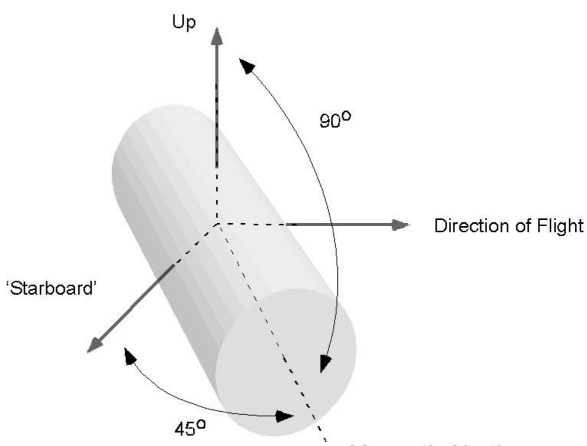
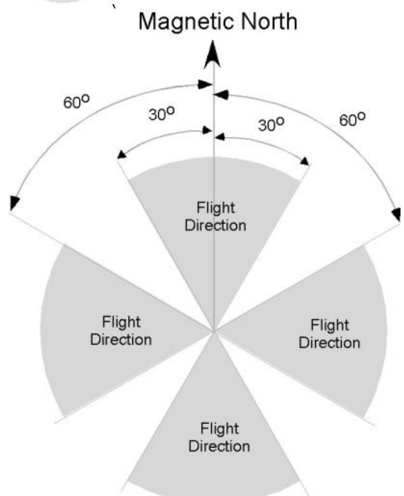


Figure 8 Equatorial latitude





Normal sensor orientation for flight in a North-South direction at the equator will be tilting the sensor backwards by 45º. Similarly for East-West flight the sensor should be tilted to the North or South by 45º. The diagram to the left shows an alternative sensor orientation for operation in equatorial latitudes. In this case the sensor is rotated about its equator by 45º allowing N-S, E-W survey lines. It includes those areas where inclination of the Earth's magnetic field is less than 25º.

There are restrictions on the direction of travel when using this sensor orientation. The bottom diagram to the left shows the flight directions where the sensor will produce adequate signal. These flight directions are 60^0 wide..

As noted earlier, we recommend the user use the program CsAz to calculate the sensor's operation for a particular inclination and survey direction in your area. This Windows program is provided on the Magnetometer Support CD supplied with your magnetometer.

4.2 Sensor attachment

An acceptable mount for the G-824A sensor will provide a stable, non-magnetic attachment to the vehicle, provide vibration dampening and allow the sensor's orientation to be adjusted with minimal effort. One example of such a mounting solution is the sensor mount available from Geometrics (P/N 27530-04). This structure is shown in Figure 10 below and is designed for attachment inside of a towed bird, a wing pod, or inside a tail mounted stinger or any circular enclosure with an inside diameter of 7 inches.

Figure 9 Sensor mount that provides for two axes of adjustment. P/N 27530-04.

4.2 Environmental Considerations

Optically pumped magnetometers are more sensitive to magnetic field variation than are proton (Overhauser) and fluxgate types. To realize the full performance of the cesium-vapor technology, special precautions must be taken during planning and execution of the installation.

Vibration

The G-824A is usually installed in aircraft and this environment presents particular challenges. Intense vibration of system circuitry can induce microphonic noise and shorten the life of system components. For performance and safety considerations the sensor, sensor driver, and system cabling are normally hard mounted to the aircraft or are hard mounted in components that are themselves firmly attached to the aircraft in structures such as stinger and wingtip pods. Some attachments points may be prone to intense vibration and we recommend the use of good quality shock mounts that are designed to isolate the G-824A components from as much of the intense vibration as possible. Special care should be taken in securing or routing the cable so that it does not encounter hard or sharp objects that could damage the cable. Those components used to mount the G-824A sensor or any or any objects near this sensor should be non-magnetic in order to minimize the system heading error.

Electronic/electromagnetic

Sources of performance problems may arise in two areas: external electromagnetic noise and errors introduced from platform motion. Electrostatic and electromagnetic signals from aircraft systems, including other sensor instrumentation, can significantly lower the signal to noise ratio of the magnetometer. An example is the "hash" created by sparking brushes in certain aircraft generators. This can be seen as a rapidly changing field value causing excessive scatter in the readings. The permanent, induced and eddy-current magnetic fields of the airplane can cause significant errors that are dependent on attitude, acceleration and heading in the earth's magnetic field. The use of a device such as the RMS Instruments' Automatic Aeromagnetic Digital Compensator, Geometrics software program MagComp or fixed passive aero-magnetic compensation techniques will help reduce these types of errors (See Geometrics technical report TR-15). Variations in electrical currents in aircraft systems will also cause shifts, bias or increased heading error in the readings. Consult with Geometrics about the compensation and noise reduction processes before installation if you are unfamiliar with the procedures used to minimize noise and platform errors.

G-824A DC power and RS 232 Data pass through a common, non-magnetic, multiconductor cable. The ground wires of this cable should not be connected to aircraft/ship ground at any place other than the aircraft battery or the optional G-824A Junction Box. We recommend keeping the DC voltage applied to the Sensor Electronics between 24 and 33volts DC for proper operation.

Temperature

The G-824A is designed to operate over an ambient temperature range of -35 to +50°C. In an enclosed region it may be necessary to providing adequate cooling by free flowing air. If the sensor and electronics are in an unconfined region, convection cooling is generally adequate. The cesium lamp only needs to dissipate 3 to 4 watts of heat and when operating in cold regions providing some insulation or baffling around the sensor will help reduce the sensor's power consumption and provide faster warm up.

The G-824A requires a minimum warm up period of 15 minutes. In cold regions the warm up period will be longer and, to avoid delay, we recommend that the sensor power be left on overnight when ambient temperatures are expected to fall below -10°C.

5.0 OPERATION

The G-824A offers a high performance internal SupremaC CM-321 Larmor Counter. The Larmor signal is not currently available for external counting. The internal counter can be set up to sample at rates from 1 sample per second to 1000 samples per second. This makes the system particularly useful when removing power grid noise or EM transmitter noise as the AC fields are not aliased in the digital data. The CM-321 also includes a strong anti-aliasing filter to remove higher frequencies from entering the bandpass of the counter.

The G-824A includes an ASCII text based configuration scheme covered in section 7.

6.0 TROUBLE SHOOTING

Operation of the G-824A is relatively simple and when trouble arises it is usually easy to recognize and correct. Table 2 shows a troubleshooting guide provided to help in quickly locating the probable cause of the most common system problems.

Table 1. Trouble shooting

Symptom	Probable Causes	Corrective Actions
Long warm-up time	Low voltage.	Increase voltage (minimum 24 VDC at the electronics) or repair the Coax cable.
	Low ambient temperature.	Thermally insulate sensor housing.
	Faulty sensor cable connection.	Disconnect sensor from electronics and carefully clean the pins and sockets.
	Defective internal sensor or electronic components.	Return sensor and electronics to Geometrics for repair.
Noisy magnetic field readings	Local field is noisy.	Locate and eliminate source of noise or relocate sensor.

Symptom	Probable Causes	Corrective Actions
Noisy magnetic field readings	Sensor not oriented correctly. Signal amplitude too low with correct orientation. Sensor cable or connector worn or damaged.	Refer to Sensor Orientation section of this manual, or use CsAz software to model magnetic field and sensor behavior, and correct orientation if necessary. Adjust signal amplitude or return sensor and electronics to Geometrics for repair. Replace sensor cable and connector assembly. Check connector on electronics bottle for wear and replace if required.
Sensor cable kinked or cut	Handling or mechanical problem.	Change handling or mechanical mount. Then replace sensor cable and connector.
Sensor connector damaged or worn	Handling, mechanical problem, accident, or normal wear.	Correct handling or mechanical problem. Then replace sensor cable and connector.
Excessive current consumption.	Damaged Power and communications cable. Defective sensor or electronics.	Replace cable. Return sensor and electronics to Geometrics for repair.

Preventing a problem is almost always less costly than correcting the problem. We recommend checking the follow items as part of any new installation or whenever an existing installation is altered. It is also recommended that these items are checked periodically as part of a scheduled platform or system safety check.

1. Power check
    a. Minimum 24 Volts DC at electronics bottle. 28VDC recommended
    b. Maximum 32 Volts DC at electronics bottle
    c. Starting current 1.75 Ampere at 28 Volts
    d. Running current 1.05 to 1.75 Ampere at 28 Volts depending upon ambient temperature
2. Connector checks
    a. Dirt or corrosion
    b. Bent pins
    c. Back-shell tight
3. Cable jacket check
    a. Kinks
    b. Abrasions
    c. Cuts
4. Sensor orientation
    a. Use CsAz to model sensor behavior
    b. Change sensor orientation and observe dead zones
    c. Return sensor to correct orientation for the survey area
5. Field readings
    a. Reasonably close to MagPick IGRF model estimate

   b. Sample to sample noise less than 0.1 nT @ 10 Hz when not moving
6. Larmor amplitude check and adjustment (Authorized Repair Facility only)
   a. Potentiometer on GSN board adjusted for 2.0 Volts Peak to Peak at 50,000 nT after 20 minute warm up

7.0 G-824A MAGNETOMETER

The CM-321 counter module is an integrated circuit that converts the cesium Larmor signal (70 kHz to 350 kHz) into a numeric value indicating the magnetic field strength in nanoTesla (20,000 nT to 100,000 nT in the earth's field). In addition there are 8 each 12 bit A/D channels where external or internal analog voltages can be digitized and appended to the output serial data. This can be useful, for instance, in digitizing an analog altimeter signal and incorporating it into the magnetometer data stream. A Julian clock string can be enabled and added to the output data stream as well. There is an External Event pin that can be used for external trigger or event marking. There is also an External Sync pin that can be used to synchronize the magnetometer to timing devices such as GPS 1PPS (pulse per second) regardless of the magnetometer sample rate.

In compliance with United States Government export restrictions, the G-824A does not output the Larmor signal for external counting. Digitized Larmor is provided to the user in RS-232 serial format from the G-824A serial port to a host computer (or Serial to USB converter, see Keyspan.com) serial Com port. The RS-232 serial string configuration and other features of the G-824A are configured by the user by choosing options from the G-824A Configuration Menu. This menu is accessed via the host computer's Serial Com port when connected to the RS-232 serial port on the G-824A.

Table 2. G-824A standard component weights and dimensions

Description	Weight	Dimensions
Cesium sensor package P/N 27516-21	1lb. 8oz.	2'3/8"x5-1/2" cylindrical housing with 168 in. cable. Termination: Burndy 0119 G6JF12-88 PNE
Electronics W/counter P/N 27735-02	2lb. 5oz.	12-5/8" including connectors. 15" long x 2-1/2" rectangular housing
Carrying Case P/N 27750-01	10 lbs.	22l" x 13081w" x 9h"
Digital signal/power cable P/N 27748-01	2lb, 2oz	25' multi-conductor Tefzel cables. Termination KPT6UHST3-18-32S, DB9 Female and tinned bare wires
Optional Digital signal/power cable P/N 27746-01	2lb, 2oz.	25' multi-conductor: Belden # 8418. Termination: KPT6UHST3-18-32S and SP06A14-19P-SR
Optional Power/data junction box P/N 24870-20	9oz.	L 4-3/4", W 3-1/4", H 3-1/4"
Optional Serial data cable P/N 60-230-237	5oz.	6', DB9
Optional AC/DC Power Supply P/N 24810-02	2lbs. (typical)	Input: 100VAC-240VAC @ 50-60 Hz; output 30VDC, 1.9A, 7" x 4" x 2.5" (typical) with 4' output cord.

The G-824A is shipped with a 25ft external signal/power/GPS PPS input interface cable, an optional power/data junction box, and an RS-232 data cable.   These components are used to connect the magnetometer to the user's 30VDC power source and logging computer. The signal/power cable also carries analog signal wires but the junction box does not break these channels out to its DB9 connector. If the user wishes to observe or record analog signal they may modify the interface cable for this purpose or contact Geometrics for instructions. To do so we recommend that electrical connection is made using a mating connector (e.g. Amphenol PT06A-18-32P, Geometrics P/N 21-103-049). The connectors used on the interface cable are of the solder type and they may be removed and reused to suit the application. Table 4 describes the pin-out of the 32 pin connector on the G-824A magnetometer. The interface cable is wired as shown on the schematic in Figure 6.

Circuit description of the external signal/power interface cable Connector type SP02A-14 -19P		
Pin #	**Function**	**Description**
A	30V power	Magnetometer power; 24 – 32VDC
B	GND	Power ground
C	TxD	From logging computer, connects to RxD of G-824
D	Rxd	To logging computer, connects to TxD of G-824
E	Aux In 1	Digital Auxiliary Channel
F	Flux X	Analog Fluxgate X Axis
G	Flux Y	Analog Fluxgate Y Axis
H	Aux In 2	Digital Auxiliary Channel
J	Current 1	Analog Current Sensor
K	Current 2 +	Analog Current Sensor
L	Current 3 -	Analog Current Sensor
M	Aux In 3	Digital Auxiliary Channel
N	ALTMTR	Analog Altimeter Channel
P	ANARET	Analog Ground
R	Aux In 4	Digital Auxiliary Channel
S	DEPTH	Analog Depth Channel
T	ANARET	Analog Ground
U	GND	Digital Ground
V	RSRET	RS 232 Return
W	Aux Out 1	Digital Auxiliary Channel
X	Flux Z	Analog Fluxgate Z Axis
Y	ANARET	Analog Ground
Z	Aux Out 2	Digital Auxiliary Channel
a	AUXRET	Auxiliary Ground
b	ANARET	Analog Ground
c	Aux Out 3	Digital Auxiliary Channel
d	VSOUNDER	Sounder Power
e	Aux Out 4	Digital Auxiliary Channel
f	AUXRET	Auxiliary Ground
g	AUXRET	Auxiliary Ground
h	AUXRET	Auxiliary Ground
j	AUXRET	Auxiliary Ground
Note: 1) All analog channels have 12 bit resolution ± 1%;		

Table 3. G-824A interface cable pin-out

7.1 CM-321 Output Format

The output data format of the G-824A is programmable. Units are pre-configured at the factory to match end user's requirements. For example each of the A/D channels can be added or removed from the output data stream by editing the CM-321 configuration page. There are several other configuration options that are discussed in detail below.

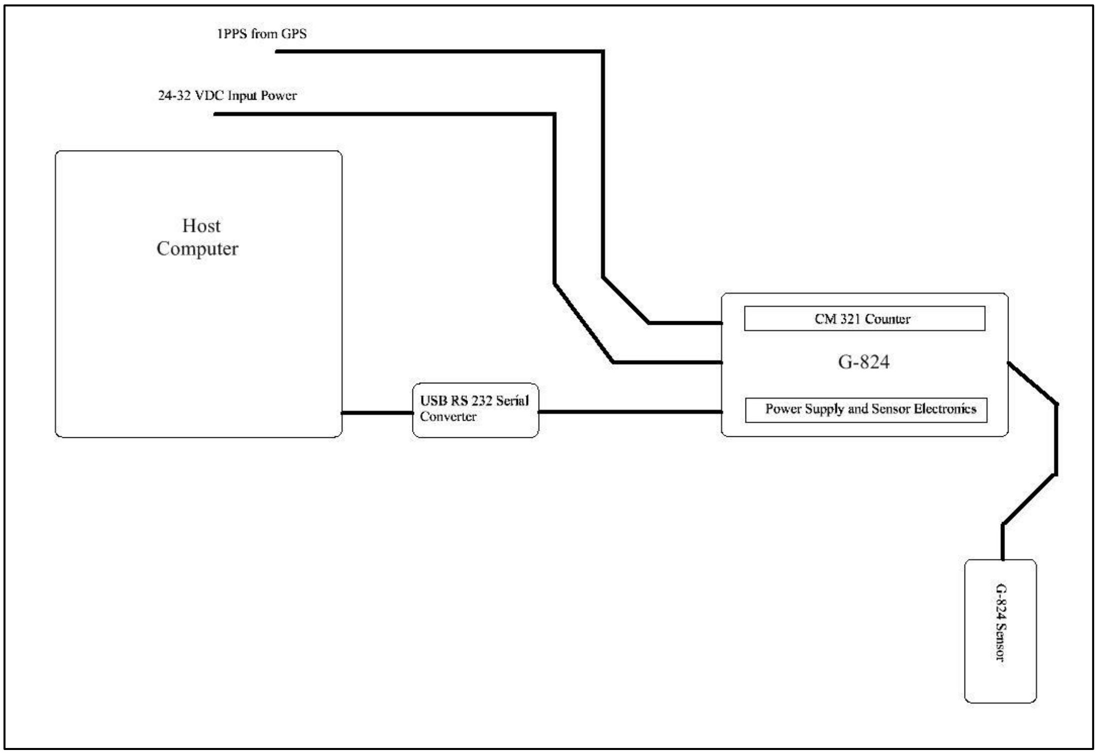


Figure 10 Block Diagram of G-824, power, PPS, and computer connections shows the standard single counter configuration. Commands from the computer are sent from the computer RS-232 transmit pin (TxD) to the counter. Magnetometer and other data are read on the computer serial port receive pin (RxD).

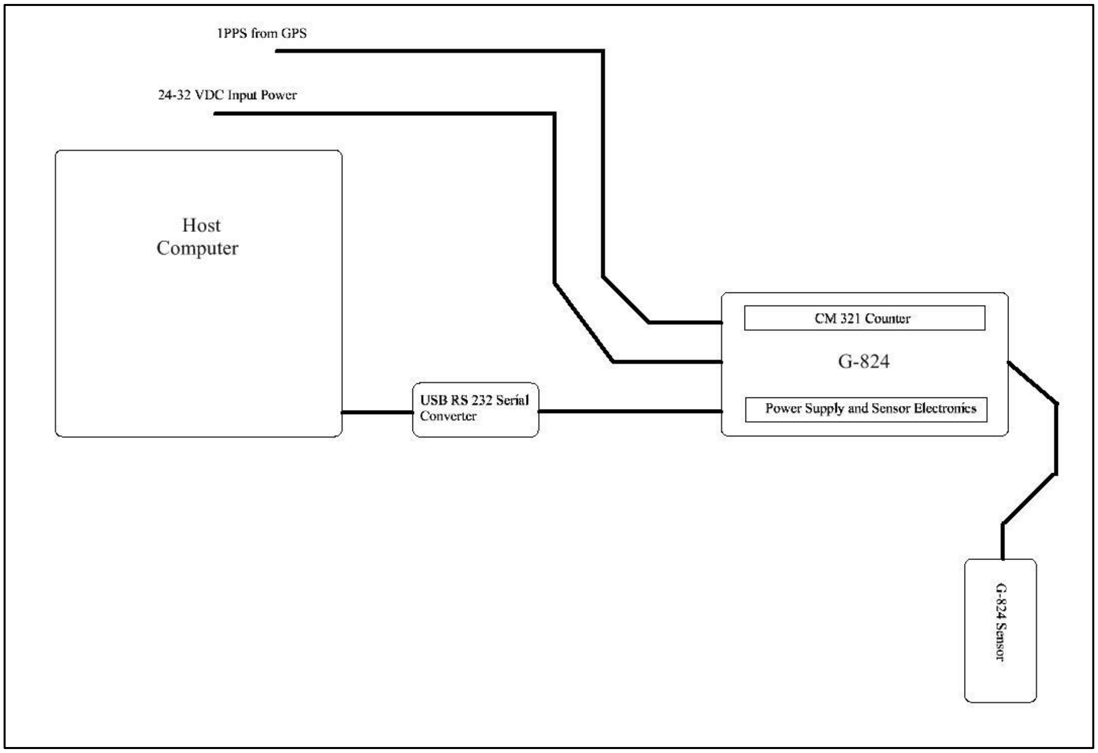


Figure 10 Block Diagram of G-824, power, PPS, and computer connections

The CM-321 may be configured with default settings specific to your survey requirements, with settings saved in internal flash RAM. When reset to default factory configuration the CM-321 counter module has the following setup parameters:

- Baud rate: 9600 baud, 8 data bits, no parity, 1 stop bit
- Cycle rate: 10 Hz
- Master Preamble character set to, $.
- Magnetometer Field: Field enabled with ######.#### format.
- Postamble character string set to CR LF, e.g., ASCII 13 (decimal) and ASCII 10 (decimal)
- Output Format: ASCII

The default output data stream contains all printable ASCII characters with each sample terminated with a carriage return/line feed sequence. Table 5 illustrates an example of this format.

Character #	Description
1	An ASCII '$' (marks first character of data stream)
2	An ASCII '1' or a blank (depending on whether Mag reading is above or below 99999.999nT).
3-7	5 digits of Mag data
8	An ASCII decimal point ['.']
9-12	4 additional digits of Mag data
13	an ASCII carriage return
14	an ASCII line feed

Table 4. Example of CM-321 default output data stream.

If the data were captured to a file and then printed the output would look like this:

```
$ 99778.1314
$ 99890.3762
$ 99955.5171
$ 99998.2933
$100078.8356
$100032.0718
$ 99979.1595
$ 86778.5089
$ 78778.2166
$ 69978.3474
```

Counter modules can be daisy chained to form synchronized multiple sensor arrays as shown in Figure 12 (to approximately 10 microsecond resolution). Note that the output data from counter 0 goes into the input port of counter 1, and so on. This allows each counter module to append its output data onto the end of the data stream coming from the previous counter(s). As each counter receives data characters from previous counters they get echoed to the next. An exception to this is the carriage return/ line feed sequence. Here, the carriage return is replaced by a comma and the line feed is ignored. Thus one long concatenated string from all counters is output from/through the last counter, and is terminated by a carriage return/ line feed sequence by the last counter only. Note that only the first counter outputs a unique preamble character (the default character is a dollar sign, '$'), and all other counters output a different preamble character (the default character is a comma, ',').

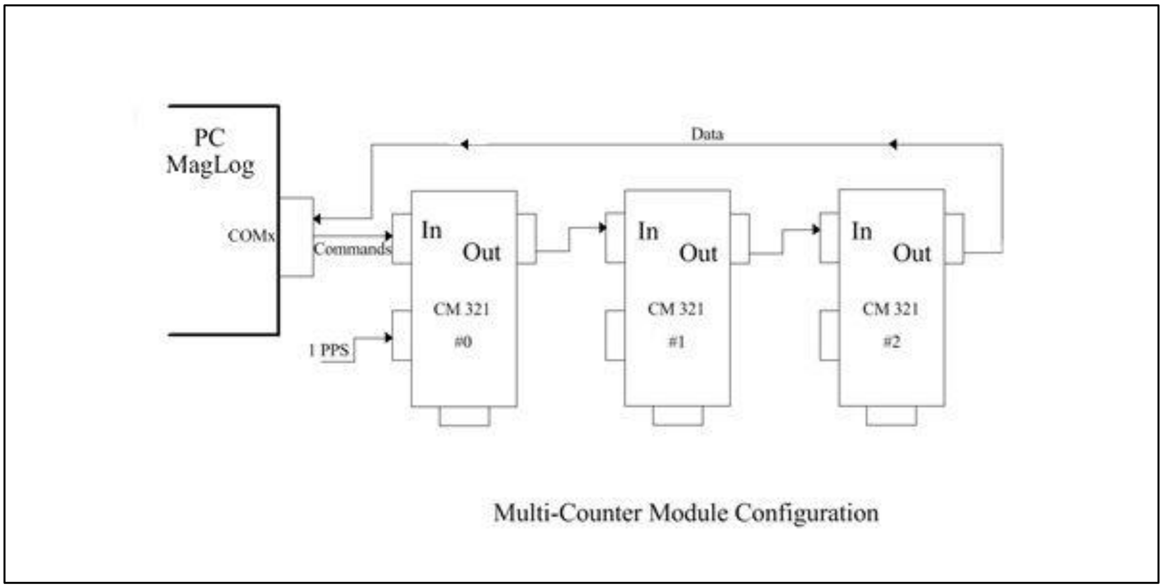


Figure 11. Schematic diagram of daisy-chained CM-321 counter modules.

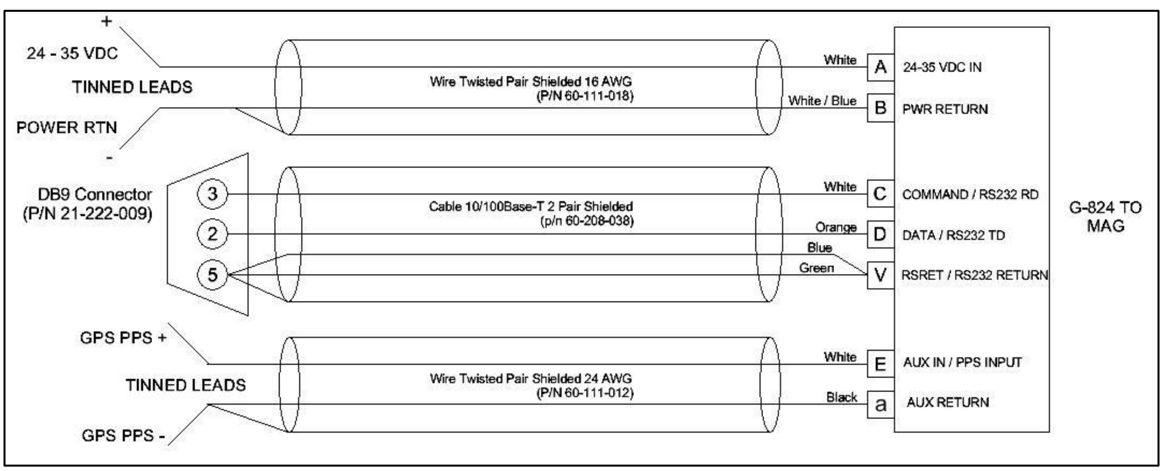


Figure 12. Wiring diagram of Interface Cable.

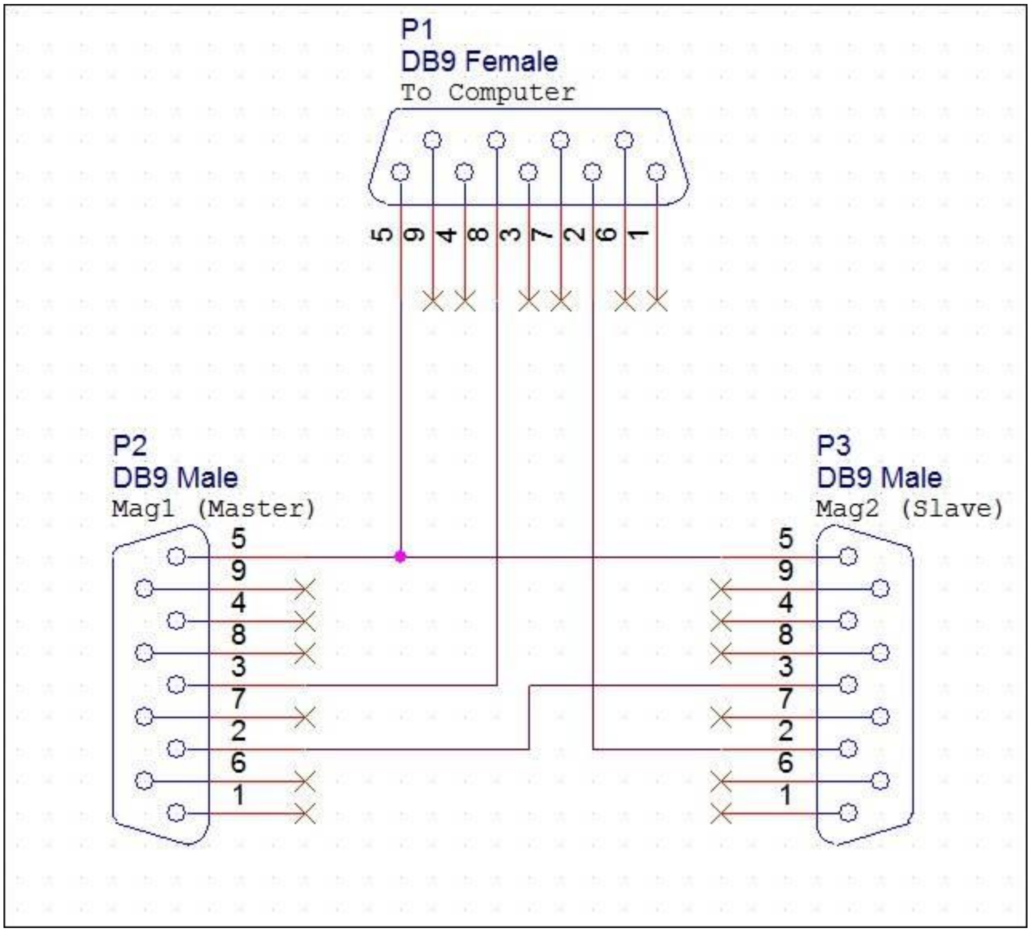


Figure 13. Concatenation Adapter to Concatenate Two Magnetometers

The above adapter takes the serial data from two standard interface cables in Figure 12 and wires them up to concatenate two magnetometers into one computer. Note that the data coming out of the master magnetometer (via P2 pin 2) goes into the command input of the slave magnetometer (P3 pin 3). The slave magnetometer then syncs its timing to the master magnetometer, as well as echo the master magnetometer data to the computer (via P1 pin 2). The slave magnetometer will also append its data to the master magnetometer data, so that the computer receives daisy chained data.

If you wanted to daisy chain in a 3'rd magnetometer then you would wire the data out from the first slave magnetometer (which is the second magnetometer in the daisy chain) would go into the command input of the second slave magnetometer (magnetometer 3 of the daisy chain). Then the data output of the second slave magnetometer (magnetometer 3) would go to the computer.

The command input to the master magnetometer is wired up to the computer, though we don't recommend that you try to send commands to the master/slave(s) via the computer. It is better to set up each magnetometer individually via the configuration menus using the standard interface cable as described below.

If you are going to also sync to a GPS via the 1PPS pulse, then set up the master magnetometer to sync to the 1PPS pulse. The slave magnetometer (s) don't need the 1PPS wired up. They will sync to the master magnetometer which is synched to the 1PPS. This way they all get synched to the 1PPS.

When setting up your magnetometers, do them one at a time using the standard output cable. Set the master up to synch with 1PPS if desired. Make sure all the baud rates and cycle times are the same. There is no master/slave setting in the configuration menus. All magnetometers when powered up are in master mode. When a magnetometer receives mag data at its command input it knows it is not at the head of the daisy chain and automatically transitions into slave mode.

Keep in mind that once a magnetometer is put into slave mode it stays in slave mode until the power is cycled. When in slave mode, the mag will not output data until it receives a full sample from the master magnetometer (or master magnetometer and previous slave magnetometers if you have more than one slave). Thus if you unplug a slave mode out of the daisy chain it will cease outputting data until you power it down, and then power it back up (putting it back into master mode).

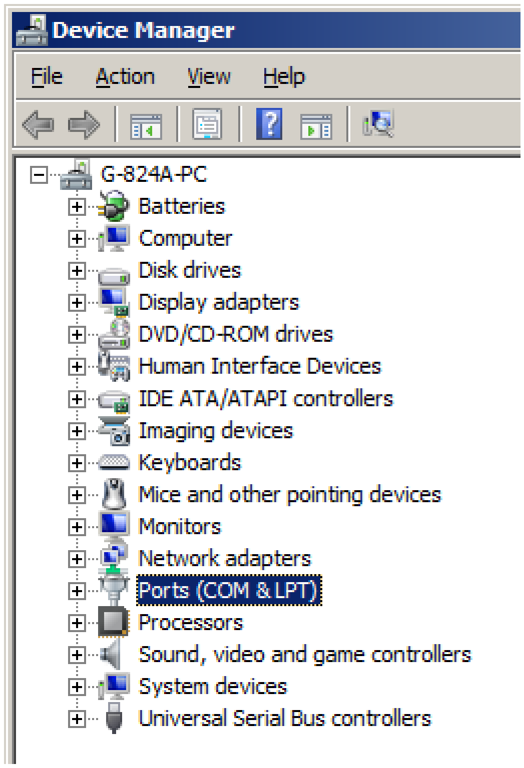
7.2 Installing Driver for USB to Serial Converter

Since today's consumer laptop and desktop computers no longer have RS-232 serial ports, it's necessary to use a USB to RS-232 SERIAL port adapter to configure and collect data from the G-824A. If your host computer does have an RS-232 Serial port, you can connect that host computer to the G-824A directly, in which case you may skip this section and advance to section 7.1.2. Geometrics has tested several USB to Serial adapters for its customers and have found two reliable models for field use. One of these is the Gearmo USA-4P-232, which is a 4-Port Serial Adapter to connect up to four serial devices to one USB port (Geometrics Part # 20-000-072), and the other is the Gearmo USA-FTDI-A36 single port adapter (Geometrics Part # 20-000-071) which is supplied with the G-824 and described here.
To install either of these USB to SERIAL adapter on your Windows computer, make sure that the USB-Serial converter is not connected to the host computer and insert the USB-Serial converter's driver installation CD into the computer's drive. You can also download the FTDI USB-Serial driver from http://www.ftdichip.com/FTDrivers.htm. Follow the instructions as prompted to install the Windows driver. These two USB-Serial adapters use the same Windows driver, so it only necessary to install the driver one time on each computer to be used. For LINUX operating systems, simply insert the USB-SERIAL converter into your computer's USB Port and go to section 7.2.1.

7.2.1 Configuring the FTDI Driver

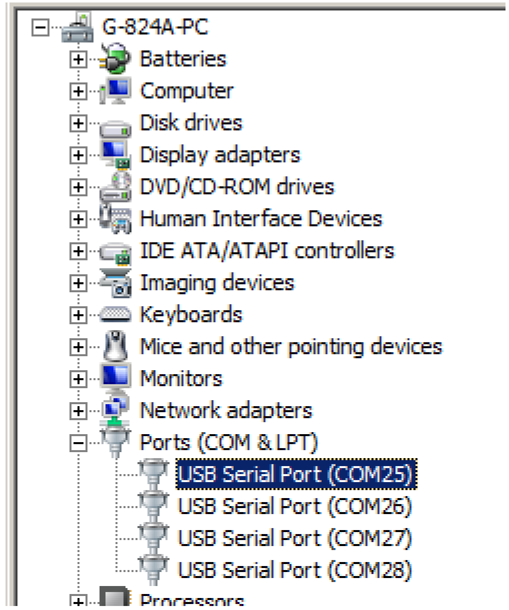
By default the adapter's driver is configured to provide maximum efficiency in terms of data transmission; this might produce an undesirable "blocking" effect on the data, causing multiple data strings to arrive at the same time due to blocking in the Windows kernel. This also has adverse effect if adapter is used with PPS based time server. To reduce above shortcomings the following configuration settings can be adjusted:

1. Plug the USB-Serial Converter into your computer to be used to interface with the G-824A, and wait 15 to 30 seconds for the USB-Serial converter to be recognized by the Windows operating system
2. Locate the "Device Manager" in your version of Windows and locate the "Ports (COM & LPT)" icon in the list (as shown below). This can be done by clicking the "START" button and typing in "Device Manager in the blank field immediately above it, and then clicking on the "Device Manager" option shown in that window.

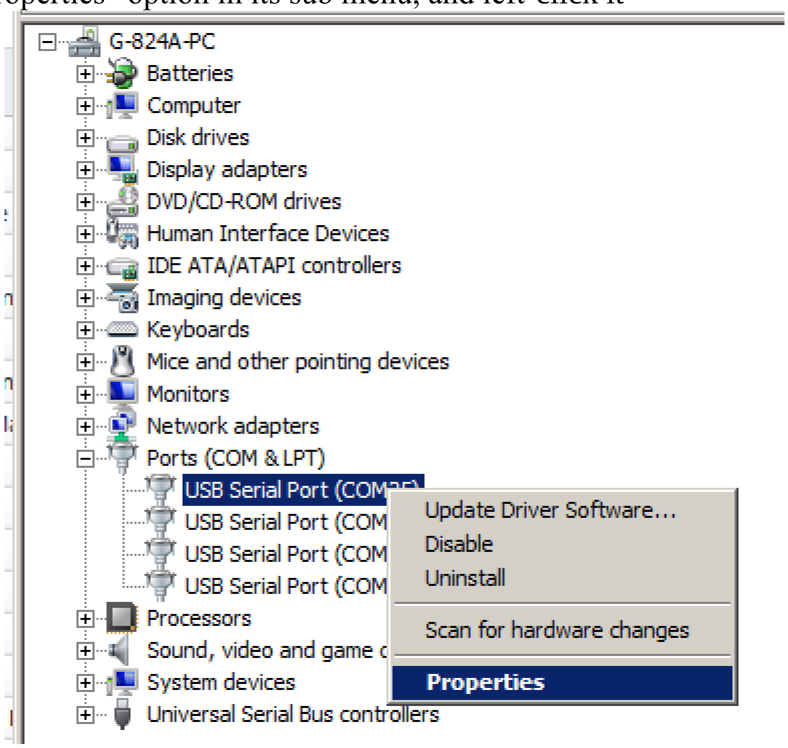


3. Left-click on the "+" or "▷"sign beside "Ports (COM & LPT)". It should show "USB Serial Port (COMxx[1]), as below. *Note that the COM port that was assigned to this device by your computer will likely be different from the example shown (COM25).*

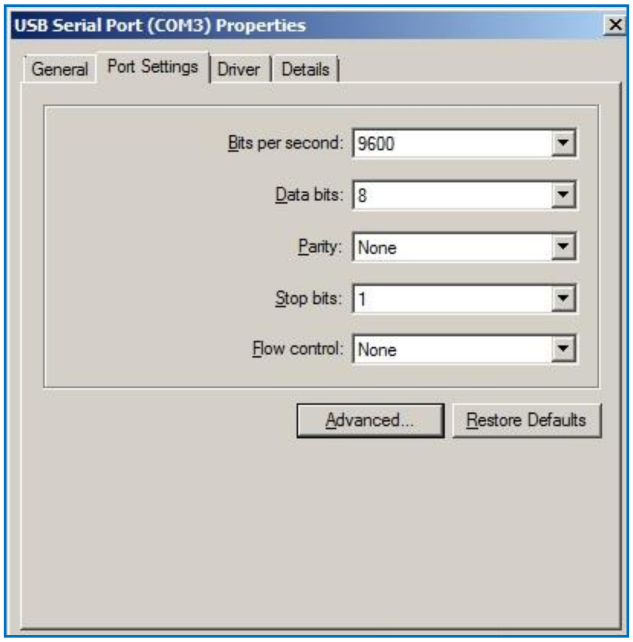
[1] "xx" here denotes port number, which could be different for different PCs and USB ports.



4. Right-click on the sub heading "USB Serial Port (COMxx)", then scroll down to the "Properties" option in its sub menu, and left-click it

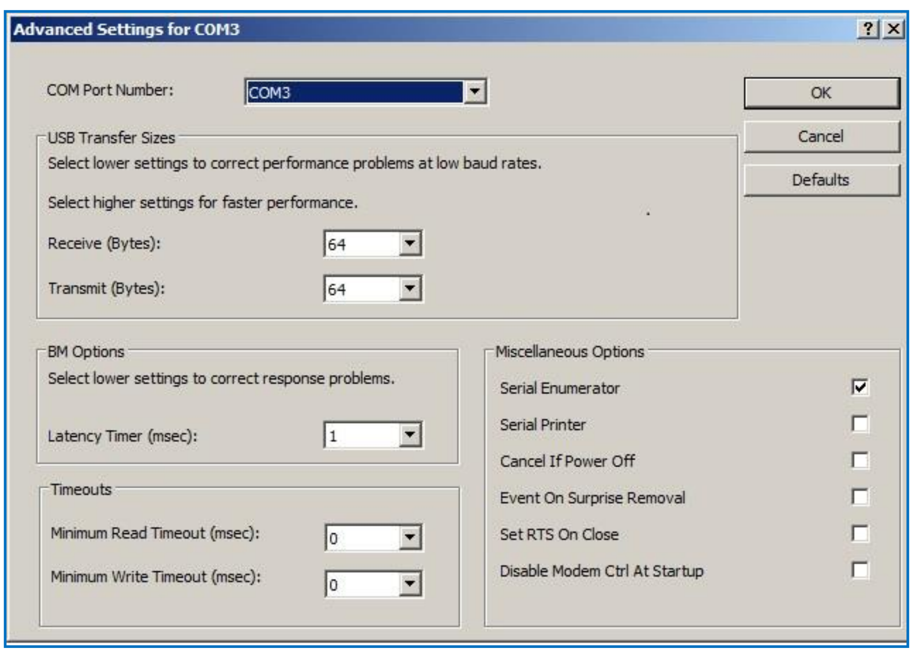


5. At the resulting "USB Serial Port (COMxx) Properties" menu, left-click the "Advanced" button.



6. At the resulting “Advanced Settings for COMxx” change the “Receive (Bytes):” to the lowest value possible by clicking on the arrow beside its value setting box and scrolling to the top (lowest) setting available. In this case the lowest setting is 64 bytes. Do the same for the “transmit (Bytes): setting as well. You will also need to adjust the “Latency Timer (mSec):” to its lowest level as well (usually 1).

These adjustment settings speed up the response time of the Windows operating system to the USB-Serial converter and are necessary to ensure reliable data collection from the converter to Windows.



Repeat this operation for all COM ports controlled by the adapter.

7.2.2 Installing Tera Term Terminal Emulator

A data terminal program capable of bi-directional communication is required to access the G-824A's configuration menu. This is achieved through the host computer's Serial RS-232 Com Port. If you already have a serial terminal program that allows bi-directional serial communication through one of your host computer's Serial RS-232 Com ports, you may skip this step and advance to section 7.3.1.

Tera Term is a program that supports RS 232 communications between a Windows PC and any connected device such as the G-824. This software is provided through LogMeTT.com, and can be downloaded through the LogMeTT web page:

http://logmett.com/index.php?/products/teraterm.html

This software is provided at no charge. Please make sure you adhere to the Tera Term License terms and conditions when you download and use this software. For LINUX operating systems contact Geometrics customer service at Support@geometrics.com.

7.2.3 Serial Data Interface

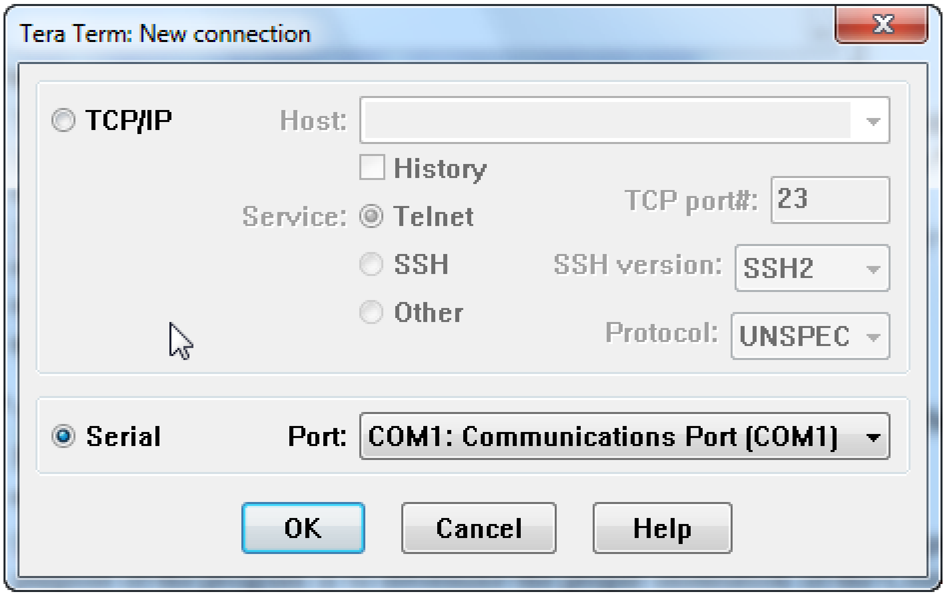
A standard RS-232 serial interface is used to communicate with the G-824A. The Port should be set to 8 data bits, 1 stop bit, no parity, and no handshaking. Baud rate must be set to at least 115,200 for high speed (250 Hz or faster sample rates. The same port is used for configuration and data collection. Run the terminal emulator software and configure it as described in section 7.3 to setup and collect G-824A data.

7.3 Detailed configuration descriptions:

The following sections contain examples of different G-824 setups. The first section illustrates how to setup the Tera Term terminal emulation program in order to communicate with the G-824. The following sections show examples of various configurations with different baud rates, sample rates, and output variables. By following though the different configurations you will be able to see the pattern necessary to create your own desired output format.

7.3.1 Tera Term, Terminal Emulator Program Setup

Install the terminal program and configure to the proper parameters for communication with the G-824. The following is a snapshot of the main page of the Tera Term Program.

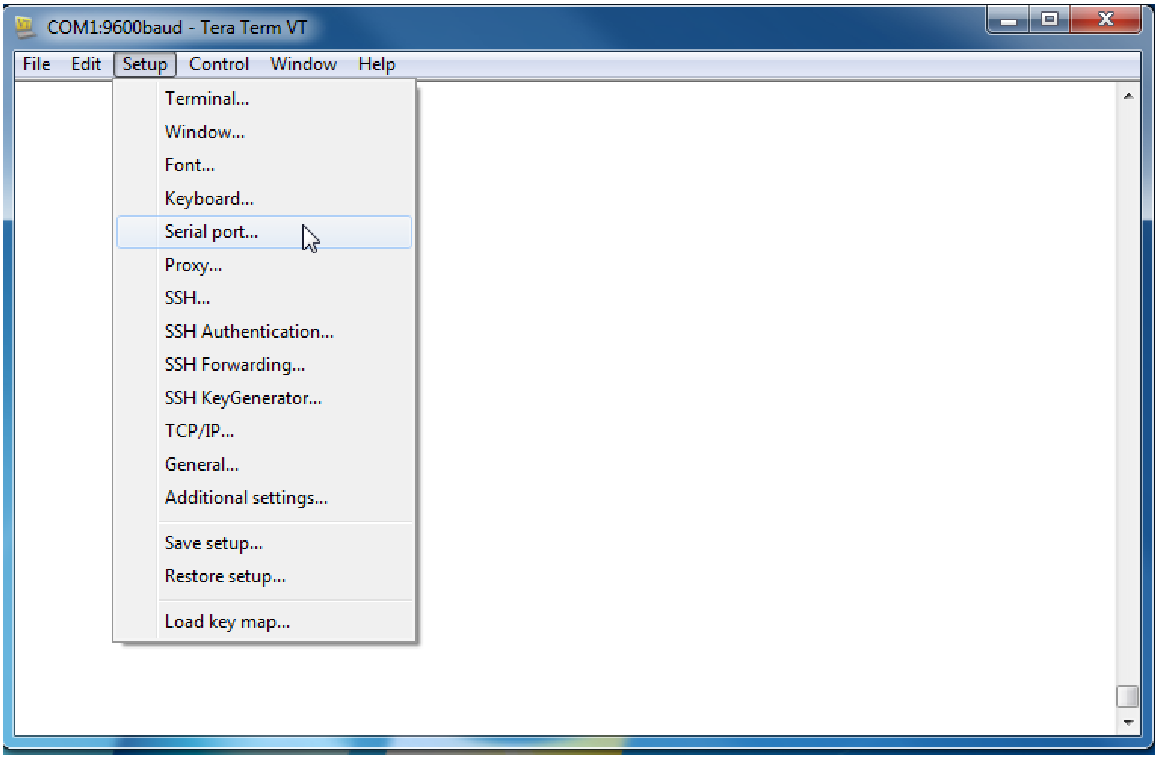


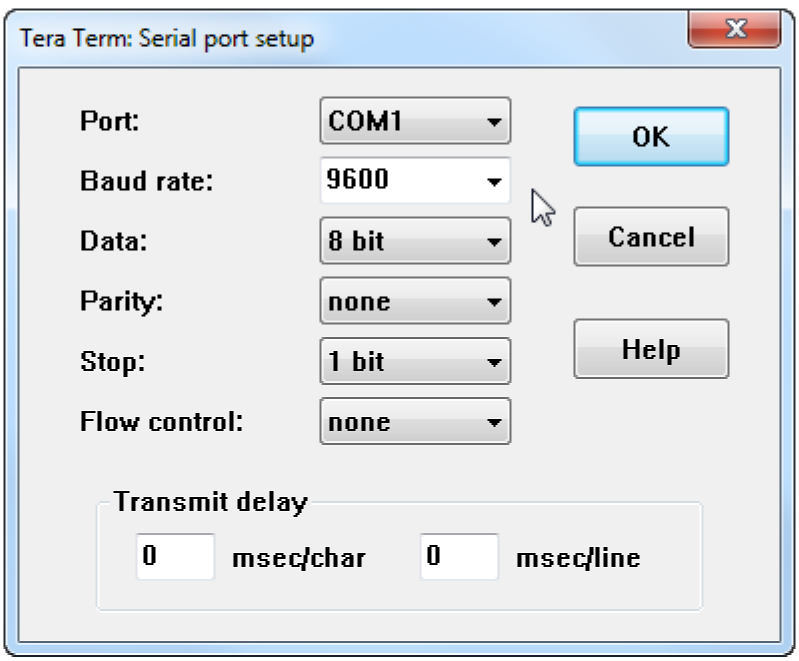
If another terminal program is being used, these same settings (115200 baud, N, 8, 1) should be used for the initial setup.

Tera Term displays a choice of TCP/IP or Serial connections at start up. Click on the Serial radio button and select the correct port from the Port: drop down list.

Tera Term defaults to 9600 Baud, 1 Start Bit, 8 Data Bits, and No Parity upon startup.

Click on the Setup menu item and select Serial port to set the Baud rate, Data bits, Parity, Stop bit, and Flow control communications parameters.





The host computer is now ready to receive, display and send configuration commands to the G-824A.

7.3.2 Wiring Connections, Turn-on Procedure, and 250 Hz ASCII Output Configuration Example

This magnetometer and integrated Larmor counter board / computer have been designed to output a wide variety of data, including instrument diagnostic data, synchronization information to geo-locate the mag readings for data processing and data collected from other serial or analog-output instruments received by the G-824 for retransmission to the host computer.

With the host computer setup and ready to communicate with the G-824A (described in previous section), connect the G-824A as follows:

A. Make sure that the power supply is turned off or disconnected.

B. Connect power supply set to 28 VDC and capable of supplying 2 amps to the Power input wires of the G-824A Power / Data wiring harness. Note that the G-824A requires good quality, low noise input power to achieve maximum performance. We recommend a linear power supply with no more than 15 mV output ripple and noise.

C. Optionally plug power cable between power supply and into the 24-32 VDC connector in the optional white DC/Data Junction Box

D. Optionally connect the junction box ONBOARD connector to the connector on the magnetometer cable 19-pin connector.

E. If required, connect the GPS PPS input cable to the PPS output of the user's GPS receiver. Note that the G-824 requires between 5 and 15 VDC pulses. Pulse polarity can be configured in the G-824 configuration menu as shown in Section **7.3.9**:

F. Connect the G-824A sensor to its sensor and position the sensor in the proper orientation (approximately 45degrees to magnetic field inclination angle). Use Geometrics CsAz program to help determine correct sensor orientation. CsAz can be download at no charge from http://www.geometrics.com/geometrics-products/geometrics-magnetometers/download-magnetometer-software/.

G. Turn on the power supply on and confirm that it is outputting 28 VDC.

H. Optionally pull and toggle up the power switch on the white Junction Box.

I. Looking at the host computer, there will be a delay of about two seconds while the magnetometer's internal power supplies initiate. Then either the G-824A configuration menu will appear (shown below) or you will see data streaming across or down the terminal's screen, depending on whether the G-824 is configured in CONFIGURE or RUN mode.

If data is continuously streaming, you will need to interrupt the data flow by pressing and holding the computer keyboard shift key and the letter Q (e.g., capital Q). You can force the magnetometer to temporarily communicate at 9600 Baud by first interrupting power; setting your terminal emulation software to 9600 Baud; then transmitting capital Q's as you apply power to the magnetometer. This procedure usually produces more reliable communications when adjusting or viewing magnetometer configuration. Successive capital Q's sent to the magnetometer will tell it to interrupt data transmission and prompt the user to type in the word ASCII (not case sensitive) and then press ENTER. The G-824 will go into its Configuration MENU as shown below. Note that with some host computers once the word ASCII is typed, there may be an error message, at which point the user should simply type ASCII again and hit ENTER. This will take the user to the configuration menu shown below:

```
File (Safe default values# (Not saved)
S/N 824113     CM321 configuration Version 00.02
Mag Code Version: 01.00  Build Date: 8/29/2013 @ 18:11:31
A Assign file name       B Baud rates            C Cycle time
D Display all settings   E Erase FLASH           F Format of output
G Gate control           I Input voltages        L Load from FLASH
M Mode of operation      N Next (multi systems)  O Other devices
P Password               R Run magnetometer      S Save parameters
T Triggering
```

This menu controls all of the user adjustable parameters for the G-824A. For our first example we will set up the magnetometer to output data in ASCII at the 250 Hz rate. We will output the magnetometer reading in the first column, the Larmor signal level in the second column and the PPS / Status byte in the third column. In the ASCII output mode, the G-824 inserts a carriage return and line feed by default. This can also be changed if required.

7.3.3 Set Cycle Time (Data Output Rate)

The first step is to set the rate at which the magnetometer acquires and transmits magnetic field readings. This is done by setting the time between each cycle, called the cycle time. For a 250 Hz output data rate, 1/250 = 4 milliseconds, so we enter 0.004. From the G-824A configuration menu we type C. The G-824A immediately responds with the following:

```
File (Safe default values# (Not saved)
S/N 824113     CM321 configuration Version 00.02
Mag Code Version: 01.00  Build Date: 8/29/2013 @ 18:11:31
A Assign file name       B Baud rates            C Cycle time
D Display all settings   E Erase FLASH           F Format of output
G Gate control           I Input voltages        L Load from FLASH
M Mode of operation      N Next (multi systems)  O Other devices
P Password               R Run magnetometer      S Save parameters
T Triggering
->
```

⇐ Type the letter C at this prompt to edit the cycle time

The cycle time is set in seconds. For example, if you want the magnetometer to cycle at a rate of 10 samples per second (10Hz), set the value to 0.100 seconds.

This setting also controls the anti-alias filter and thus is still needed when external triggering is used.
Cycle Time should be set to the rate the trigger pulses are expected to occur.

Cycle time in seconds : 0.004 ⇦ Use the backspace to edit the number and hit ENTER (0.004 = 250 Hz)

The G-824A accepts the reading and re-displays the configuration menu for the user (below).

File (Safe default values# (Not saved)
S/N 824113 CM321 configuration Version 00.02
Mag Code Version: 01.00 Build Date: 8/29/2013 @ 18:11:31
A Assign file name B Baud rates C Cycle time
D Display all settings E Erase FLASH F Format of output
G Gate control I Input voltages L Load from FLASH
M Mode of operation N Next (multi systems) O Other devices
P Password R Run magnetometer S Save parameters
T Triggering

->

7.3.4 Set Format Output Of Data

To set up the magnetometer data output format type F on the host computer at the configuration menu prompt. This allows us to change the "Format of Output". There will be a series of questions provided which allow us to reconfigure the data output format. The current setting of each parameter is shown after each question. It can either be left as default by simply pressing ENTER or edited with the backspace key. Each parameter's order in the output string can also be adjusted by assigning a particular "display position" when prompted. The series of questions is shown below. Note that most items have a display position of "0". This means the item is not in the output data stream. In the following configuration list note that there are three configuration items in the output data stream:

1) The field value at position 1 with a format of #####.##### (5 digits before and after the decimal)
2) The signal strength at position 2 with a format of #.# (1 digit before and one after the decimal point).
3) The status bytes at position 3 with two bytes.

After typing “F” at the configuration menu prompt you will see the following menu items:

```
Specify the digital output RS-232 format.

The transmission order of the data source is controlled
by setting the "display position" in the following
table.

The format of the transmitted numbers is controlled by the
format control in the form "###.####".  Only the digits you
specify are output, the others are ignored.  For example,
15.62 formatted with "#.#" will produce "5.6".

Output format :
(0=ASCII 1=XS3 ):0
Put commas between numbers :
(0=No 1=Yes ):0
Remove unneeded spaces and zeros :
(0=No 1=Yes ):0
Master preamble :$
Slave preamble :,
Field display position (1=first, 2=second etc) : 1
Field display format :######.#####
```

Display Position 1
Format #####.#####

```
Time display position (0=none,1=first,2=second..etc) : 0
Number of decimals in seconds : 1
Date display position (0=none,1=first,2=second..etc) : 0
Fid. number display position (0=none,1=first,2=second..etc) : 0
Fid. number display format :######
Signal display position (0=none,1=first,2=second..etc) : 2
Signal display format :#.#
```

Display Position 2
Format #.#

```
Depth display position (0=none,1=first,2=second..etc) : 0
Depth display format :####.###
Altimeter display position (0=none,1=first,2=second..etc) : 0
Altimeter display format :####.###
ADC[3] display position (0=none,1=first,2=second..etc) : 0
ADC[3] display format :####.###
ADC[4] display position (0=none,1=first,2=second..etc) : 0
ADC[4] display format :####.###
ADC[5] display position (0=none,1=first,2=second..etc) : 0
ADC[5] display format :####.###
ADC[6] display position (0=none,1=first,2=second..etc) : 0
ADC[6] display format :####.###
ADC[7] display position (0=none,1=first,2=second..etc) : 0
ADC[7] display format :####.###
```

ADC[8] display position (0=none,1=first,2=second..etc) : 0
ADC[8] display format :####.###
Aux input #1 display position (0=none,1=first,2=second..etc) : 0
Aux input #2 display position (0=none,1=first,2=second..etc) : 0
Aux input #3 display position (0=none,1=first,2=second..etc) : 0
Aux input #4 display position (0=none,1=first,2=second..etc) : 0
Lamp brightness display position (0=none,1=first,2=second..etc) : 0
Lamp brightness display format :##.#
Heater effort display position (0=none,1=first,2=second..etc) : 0
Heater effort display format :##.#
Lamp effort display position (0=none,1=first,2=second..etc) : 0
Lamp effort display format :##.#
supply voltage display position (0=none,1=first,2=second..etc) : 0
supply voltage display format :###.#
Pressure supply monitor display position (0=none,1=first,2=second..etc) : 0
Pressure supply monitor display format :##.#
Sounder supply monitor display position (0=none,1=first,2=second..etc) : 0
Sounder supply monitor display format :###.#
Fluxgate supply monitor display position (0=none,1=first,2=second..etc) : 0
Fluxgate supply monitor display format :##.#
+12V supply monitor display position (0=none,1=first,2=second..etc) : 0
+12V supply monitor display format :##.#
+5V supply monitor display position (0=none,1=first,2=second..etc) : 0
+5V supply monitor display format :#.###
+3.3V supply monitor display position (0=none,1=first,2=second..etc) : 0
+3.3V supply monitor display format :#.###
-5V supply monitor display position (0=none,1=first,2=second..etc) : 0
-5V supply monitor display format :#.###
Mag. supply monitor display position (0=none,1=first,2=second..etc) : 0
Mag. supply monitor display format :##.#
Hemisphere detector display position (0=none,1=first,2=second..etc) : 0
Hemisphere detector display format :##.#
Status display position (0=none,1=first,2=second..etc) : 3 ← Display Position 3
Status display format :# ← Format #
Include a CheckSum in the data :
(0=No 1=Yes):0
Character to put before the checksum for ASCII data :*
Postamble for ASCII data :\r\n
Postamble for XS3 data :*

Once all of the FORMAT OF OUTPUT prompts have been answered, the G-824A will return the user to the Configuration menu again (below).

```
File (Safe default values# (Not saved)
S/N 824113     CM321 configuration Version 00.02
Mag Code Version: 01.00  Build Date: 8/29/2013 @ 18:11:31
A Assign file name      B Baud rates          C Cycle time
D Display all settings  E Erase FLASH         F Format of output
G Gate control          I Input voltages      L Load from FLASH
M Mode of operation     N Next (multi systems)  O Other devices
P Password              R Run magnetometer    S Save parameters
T Triggering
```

7.3.5 Saving Settings In Memory

The next step is to save the adjusted settings in the G-824A memory such that they will then be what will be used the next time the magnetometer is powered on. To do this, type S at the Configuration Menu prompt. The following is then shown:

```
Checking

The selected baud rate
Main RS-232 Baud Rate :   115200
is not a standard Baud rate.
Press "Y" to ignore the warning and save
the settings to FLASH.

Press any other key to abort: Saving a file can take several seconds.
Press "Y" to proceed or any other key to abort.

The operation complete successfully.
```

Press Y at both prompts to save the settings and continue and be brought back to the Configuration Menu again.

Make sure you see this message, which indicates a successful save.

Checking. There is no room. You must erase a file first to make room before you can save.

If you see this message, your changes were NOT saved, and you must Erase FLASH first; then attempt to save again. Type E to begin the Erase Flash function to erase one or more saved configurations.

```
File (Safe default values#
S/N 824113     CM321 configuration Version 00.02
Mag Code Version: 01.00  Build Date: 8/29/2013 @ 18:11:31
A Assign file name      B Baud rates          C Cycle time
D Display all settings  E Erase FLASH         F Format of output
G Gate control          I Input voltages      L Load from FLASH
M Mode of operation     N Next (multi systems)  O Other devices
P Password              R Run magnetometer    S Save parameters
T Triggering
```

7.3.6 Start G-824 Data Transmission

Now that the G-824A has been configured and the settings saved the settings in the magnetometers flash memory, the magnetometer can be commanded to start outputting readings from the Configuration menu by typing R.   The following is observed:

```
Checking

The selected baud rate
Main RS-232 Baud Rate :   115200
is not a standard Baud rate.
<HR>
Press "Y" to ignore the warning.$$     0.00000 26.7 62
$  6338.32834 26.7  0
$ 20961.15197 26.7  0
$ 28898.15558 26.7  0
$ 28550.66295  3.5  0
$ 28550.66333  3.5  1
$ 28550.66359  3.5  0
```

Type Y again to continue

7.3.7 Setting the Power Up Mode:

The G-824 can power up into two different modes. The default mode powers up and enters the main configuration menu as follows:

```
File (Safe default values# (Not saved)
S/N 824113     CM321 configuration Version 00.02
Mag Code Version: 01.00  Build Date: 8/29/2013 @ 18:11:31
A Assign file name      B Baud rates          C Cycle time
D Display all settings  E Erase FLASH         F Format of output
G Gate control          I Input voltages      L Load from FLASH
M Mode of operation     N Next (multi systems)  O Other devices
P Password              R Run magnetometer    S Save parameters
T Triggering
```

From this menu you must choose “R” and press ENTER to start the magnetometer serial output stream. The other power up mode goes directly into outputting data, skipping the main configuration menu. To change between these modes, from the main configuration menu chose “M” and press ENTER. You will see the following submenu listed below.

[Note: If the G-824 is configured to start up outputting data and skipping the configuration menu then type a continuous stream of upper case Q’s until the main menu appears. See section 7.3.2 for getting to the main configuration menu from a continuously streaming data stream].

This parameter specifies what the magnetometer will do the next
time power is applied.
*
*
The magnetometer can either return to the
configuration mode or run as a magnetometer.

You must save the settings for this to be effective.

Power on, run mode :
(0=Configure 1=Magnetometer):1

Backspace and type “0” to power up into configuration menu
or
Backspace and type “1” to power up directly into outputting data

Press ENTER to get back to main menu. You must Save the new setting for it to remember the changes on the next power up. Type S for Save Parameters and you will get the following submenu:

Checking

The selected baud rate
Main RS-232 Baud Rate :   115200
is not a standard Baud rate.
Press "Y" to ignore the warning and save
the settings to FLASH.

Press Y

Press any other key to abort:Saving a file can take several seconds.
Press "Y" to proceed or any other key to abort.

Press Y

The operation complete successfully.

Make sure you see this message, which indicates a successful save.

Checking. There is no room. You must erase a file first to make room before you can save.

If you see this message, your changes were NOT saved, and you must Erase FLASH first; then attempt to save again. Type E to begin the Erase Flash function to erase one or more saved configurations.

The power up Mode is now saved.

7.3.8 XS3 Data Output Format with 1000 Hz Output Rate Example

XS3 is an alternate compressed binary data output format that the G-824A can accommodate for high speed data transmissions.   The key advantage of this format is that it can pack two bytes of text into one ASCII character.   This next example shows the importance of XS3 format feature, which is described in detail in Section **7.4**.

To set up the G-824A to output at a 1000 Hz rate, record the Larmor signal level (to allow sensor orientation adjustment) and record the Status/ PPS Byte (for synchronization of the data and to confirm proper magnetometer operation), perform the following procedures:

1. Power up the magnetometer as described in the previous example
2. Hold down on the SHIFT key and then the Q key on the computer keyboard to stop the magnetometer output and go to the configuration menu ASCII prompt (otherwise go to step 3).
3. Type ASCII to enter the G-824A's configuration menu. (You may need to type ASCII twice if you get a "web page" error after typing it the first time.
4. At the Configuration window Type C. Use the backspace key to edit the Cycle time to show 0.001 which corresponds to 1 millisecond output (1000 Hz rate). Hit ENTER, and you will be taken back to the configuration menu.
5. Hit F to edit the Format menu. You will see a series of questions that need to be edited as follows:

File (Safe default values) (Not saved)

S/N 824113 CM321 configuration Version 00.02

Mag Code Version: 01.00 Build Date: 8/29/2013 @ 18:11:31

A Assign file name B Baud rates C Cycle time

D Display all settings E Erase FLASH F Format of output

G Gate control I Input voltages L Load from FLASH

M Mode of operation N Next (multi systems) O Other devices

P Password R Run magnetometer S Save parameters

T Triggering

-> ⇐ Type F at this prompt to edit the data output

Specify the digital output RS-232 format.

The transmission order of the data source is controlled by setting the "display position" in the following table.

The format of the transmitted numbers is controlled by the format control in the form "###.####". Only the digits you specify are output, the others are ignored. For example, 15.62 formatted with "#.#" will produce "5.6".

Output format :

(0=ASCII 1=XS3):1 ⇐ Use backspace and edit this field to show 1 for XS3

Put commas between numbers :

(0=No 1=Yes):0

Remove unneeded spaces and zeros :

(0=No 1=Yes):0

Master preamble :$

Slave preamble :,

Field display position (1=first, 2=second etc) : 1

Use backspace and edit the display position to 1

Field display format :#####.###

Use backspace and edit this field to show #####.### (8 characters = 4 ASCII Bytes)

Time display position (0=none,1=first,2=second..etc) : 0

Number of decimals in seconds : 1

Date display position (0=none,1=first,2=second..etc) : 0

Fid. number display position (0=none,1=first,2=second..etc) : 0

Fid. number display format :######

Signal display position (0=none,1=first,2=second..etc) : 2

Use backspace and edit the display position to 2

Signal display format :#.#

Use backspace and edit this field to show #.# (3 characters = 2 ASCII Bytes)

Depth display position (0=none,1=first,2=second..etc) : 0

Depth display format :####.###

Altimeter display position (0=none,1=first,2=second..etc) : 0

Altimeter display format :####.###

ADC[3] display position (0=none,1=first,2=second..etc) : 0

ADC[3] display format :####.###

ADC[4] display position (0=none,1=first,2=second..etc) : 0

ADC[4] display format :####.###

ADC[5] display position (0=none,1=first,2=second..etc) : 0

ADC[5] display format :####.###

ADC[6] display position (0=none,1=first,2=second..etc) : 0

ADC[6] display format :####.###

ADC[7] display position (0=none,1=first,2=second..etc) : 0

ADC[7] display format :####.###

ADC[8] display position (0=none,1=first,2=second..etc) : 0

ADC[8] display format :####.###

Aux input #1 display position (0=none,1=first,2=second..etc) : 0

Aux input #2 display position (0=none,1=first,2=second..etc) : 0

Aux input #3 display position (0=none,1=first,2=second..etc) : 0

Aux input #4 display position (0=none,1=first,2=second..etc) : 0

Lamp brightness display position (0=none,1=first,2=second..etc) : 0

Lamp brightness display format :##.#

Heater effort display position (0=none,1=first,2=second..etc) : 0

Heater effort display format :##.#

Lamp effort display position (0=none,1=first,2=second..etc) : 0

Lamp effort display format :##.#

supply voltage display position (0=none,1=first,2=second..etc) : 0

supply voltage display format :###.#

Pressure supply monitor display position (0=none,1=first,2=second..etc) : 0

Pressure supply monitor display format :##.#

Sounder supply monitor display position (0=none,1=first,2=second..etc) : 0

Sounder supply monitor display format :###.#

Fluxgate supply monitor display position (0=none,1=first,2=second..etc) : 0

Fluxgate supply monitor display format :##.#

```
+12V supply monitor display position (0=none,1=first,2=second..etc) : 0
+12V supply monitor display format :##.#
+5V supply monitor display position (0=none,1=first,2=second..etc) : 0
+5V supply monitor display format :#.###
+3.3V supply monitor display position (0=none,1=first,2=second..etc) : 0
+3.3V supply monitor display format :#.###
-5V supply monitor display position (0=none,1=first,2=second..etc) : 0
-5V supply monitor display format :#.###
Mag. supply monitor display position (0=none,1=first,2=second..etc) : 0
Mag. supply monitor display format :##.#
Hemisphere detector display position (0=none,1=first,2=second..etc) : 0
Hemisphere detector display format :##.#
Status display position (0=none,1=first,2=second..etc) : 3
Status display format :#
Include a CheckSum in the data :
(0=No 1=Yes ):0
Character to put before the checksum for ASCII data :*
Postamble for ASCII data :\r\n
Postamble for XS3 data :*
```

Use backspace and edit the display position to 3

Use backspace and edit this field to show # (1 characters = 1 ASCII Byte in Excess 3 mode)

```
File (Safe default values) (Not saved)
 S/N 824113     CM321 configuration Version 00.02
 Mag Code Version: 01.00  Build Date: 8/29/2013 @ 18:11:31
A Assign file name      B Baud rates          C Cycle time
D Display all settings   E Erase FLASH         F Format of output
G Gate control          I Input voltages       L Load from FLASH
M Mode of operation     N Next (multi systems)  O Other devices
P Password              R Run magnetometer      S Save parameters
T Triggering
```

⇐ Type S at this prompt to save these settings (type Y at both prompts as before to complete the save process)

You can now type R to run the magnetometer and view the XS3 data being output at 1000 Hz. A description of the XS3 format (including decoding) is in section 7.4. The following is an XS3 data example (note $=start,*=end).


```
$[ˆ9“63*$[ˆ9˜63*$[ˆ9›63*$[ˆ9œ63*$[ˆ9š63*$[ˆ9•63*$[ˆ9Š63*$[ˆ9Š63*$[ˆ9‹63*$[ˆ9•63*$[ˆ9£63*$[ˆ9¥63*$[ˆ9š63*$[ˆ9”63*$[ˆ9“
63*$[ˆ9•63*$[ˆ9•63*$[ˆ9”63*$[ˆ9•63*$[ˆ9˜63*$[ˆ9›63*$[ˆ9›63*$[ˆ963*$[ˆ9Š63*$[ˆ9ˆ63*$[ˆ9“63*$[ˆ9š63*$[ˆ9š63*$[ˆ9™63*$[ˆ
9—63*$[ˆ9Œ63*$[ˆ9‰63*$[ˆ9‹63*$[ˆ9“63*$[ˆ9•63*$[ˆ9˜63*$[ˆ9˜63*$[ˆ9˜63*$[ˆ9—63*$[ˆ9”63*$[ˆ9‹63*$[ˆ9Œ63*$[ˆ9–
63*$[ˆ9š63*$[ˆ9›63*$[ˆ9š63*$[ˆ9™63*$[ˆ9”63*$[ˆ9‰63*$[ˆ9Š63*$[ˆ9•63*$[ˆ9›63*$[ˆ9¥63*$[ˆ9¤63*$[ˆ9š63*$[ˆ9–
63*$[ˆ9‹63*$[ˆ9Š63*$[ˆ9”63*$[ˆ9™63*$[ˆ9¤63*$[ˆ9¤63*$[ˆ9›63*$[ˆ963*$[ˆ9“63*$[ˆ9Š63*$[ˆ9‰63*$[ˆ9Š63*$[ˆ9•63*$[ˆ9™6
3*$[ˆ9˜63*$[ˆ9”63*$[ˆ9‹63*$[ˆ9Œ63*$[ˆ9Œ63*$[ˆ9Œ63*$[ˆ9–63*$[ˆ9›63*$[ˆ9£63*$[ˆ9œ63*$[ˆ9–63*$[ˆ9Œ63*
```

7.3.9 PPS Synchronization

Almost all survey-grade GPS receivers have a PPS output. This PPS can be connected via the shielded twisted pair cable that comes out of the G-824A Interface cable for mag data synchronization with GPS. The G-824A PPS input can be configured in the G-824A with a positive pulse (trigger on the rising edge) or a negative pulse (trigger on the falling edge). De-bounce is accomplished by disarming the synchronization whenever the pulse is detected; then rearming the synchronization just after the trailing pulse is detected. This ensures that the mag is not synchronizing on an electrical noise spike. Note that synchronization corresponds to the actual rising (or falling) edge of the pulse and thus there is no delay in the timing. The G-824 can synchronize with inputs ranging from 0.2 Hz to 500 Hz timing.

Normally when the magnetometer cycle rate is configured it will set the cycle time to that value using the internal timing clock inside the G-824. Although this is a fairly accurate clock it is asynchronous to the 1PPS (pulse per second) clock coming out of the GPS. If it is desired to phase lock the configured cycle time to the GPS 1PPS clock then wire the 1PPS input cable to the GPS 1PPS output port. Then configure the 1PPS phase locking as outlined below. Only the Master magnetometer in concatenated systems needs to be connected to the GPS 1PPS.

After the 1PPS phase locking is turned on the magnetometer will synchronize its cycle time with the incoming PPS signal from the GPS such that one of the mag readings will correspond to the rising or falling edge of the PPS. In addition, since the G-824 cycle time and the 1PPS signal are in lock step with one another, the number of samples output per each 1PPS period will be constant. For example, if the cycle time is set to 4 milliseconds (250 samples per second) then there will always be 250 samples between each 1PPS event, and the timing between the sample gate beginning and end relative to the 1PPS edge will be constant as well.

Note that the phase locking function has a narrow locking range. It is assumed that the 1PPS pulse is accurate and that the internal cycle rate is fairly accurate. Contact Geometrics before attempting to use the 1PPS synch function to lock the cycle rate to anything other than an accurate GPS 1PPS signal.

The 1 PPS pulse width should be at least 120 µSeconds long, and its amplitude should be greater than +2 Volts and less than + 30 Volts for a logic high. A logic low is a voltage between +0.2V to -30V. The input impedance on the 1PPS input pin (Aux1) is 5K to ground (typical).

To synch on the rising or falling edge of the 1PPS signal is selected in the Trigger section of the Configuration menu. A status byte can be configured to be placed in the output data stream. When the magnetometer is warmed up and has a lock on the local field, the Status Byte will be zero for readings between PPS pulses and 1 for a reading corresponding to the PPS signal. The status byte is in the format section of the main Configuration menu.

For an example on how to turn on the status byte in the output data stream see section 7.3.4. In that example the status byte in configured to be in the output data stream at position #3. Below is a snip of output data showing the status byte in the configuration described in 7.3.4:

```
$ 28550.66310 3.7  0
$ 28550.66301 3.7  0
$ 28550.66287 3.6  0
$ 28550.66295  3.5  0
$ 28550.66333  3.5  1   <=
$ 28550.66359  3.5  0
```

1 here in the status column indicates that this reading is synchronized to a PPS event as seen by the G-824A's PPS input.

Here is an example on how to turn on the 1PPS phase locking function. From the main configuration menu select T to get to the triggering submenu. The following submenu items will need to be set:

```
If triggering is enabled, when the edge on the trigger
input occurs, the current field value in memory
is captured and sent to the digital output.

Phase locking is used to precisely align the sample timing
and prevent sample frequency drift.  Typically it is used
with a GPS's 1PPS signal.

An edge on the trigger input also causes the "Status"
number to become an odd number for one sample.
You can enable the display of the "Status" number
in the "Format" menu, if desired.

Trigger/PLL input :
(0=Normal 1=Aux1 2=Aux2 3=Aux3 4=Aux4 5=RS-232 ):1
Trigger/PLL input sense :
(0=Rising 1=Falling ):0
Enable external triggering :
(0=No 1=Yes ):0
Enable phase locking :
(0=No 1=Yes ):1
Concatenation/Trigger character :$
ASCII mode concatenation termination character :\r
XS3 mode concatenation termination character :*
```

- Trigger/PLL input: Select Aux1 by changing this to a 1 (if not already)
- Trigger/PLL input sense: Set to 0 or 1 depending on which PPS edge is desired
- Enable external triggering: Set to 0 since we are not externally triggering the magnetometer
- Enable phase locking: Set to 1 to enable phase locking the cycle time to GPS

Be sure to save the configuration before powering down or all changes will be lost.

7.3.10 Gate Control

Additional control of G-824 counting can be accomplished by applying a logic signal to one of the trigger inputs of the electronics console connector and setting up Gate Control. It is possible to use Gate Control to inhibit counting during EM system transmit to reduce interference in magnetometer measurements during the time that the EM antenna coil is energized. The following submenu items can be set:

Gating allows the magnetometer to ignore changes in the field value during a short period of time. It can be used to allow the magnetometer to be used with an EM system.

When gating is enabled, the unit only measures the field when the selected input is in the "true" or "active" state.

Gate input :
(0=none 1=Aux1 2=Aux2 3=Aux3 4=Aux4 5=RS-232):0 2
Gate input sense :
(0=High is true 1=Low is true):0

Be sure to save the configuration before powering down or all changes will be lost.

7.3.11 Magnetometer Operational Status

This same status byte described in the section 7.3.9 will be changed to a “2” when the counter's output is outside the range of the earth's field (as is the case when the unit is first turned on and warming up), or there has been a change in the magnetometers settings while it is outputting data, or there is a problem with cycle timing with the magnetometer's Larmor counter. Outputting all five bytes of the status number will enable the user to distinguish between the error messages in the event of a problem but may not be possible at the highest sample rates.

7.4 XS3 Data Output Format

XS3 is an industry-standard data decoding system that permits two decimal characters to be packed into one ASCII byte, doubling the amount of data that can be sent to the host computer by the G-824A. This is an important feature as it helps address the limitation of the magnetometer's 115,200 baud rate when outputting data at the full 1000 readings per second. XS3 is similar to Packed BCD but each byte has 03 HEX subtracted. This results in data that is entirely printable ASCII characters, which can be examined with a standard text editor.
The process of converting the XS3 format data into ASCII is explained in following steps:

Step 1. Decode XS3 into digits: each byte of the input data is taken in turn and compared to the value 0x30. If it is less that 0x30, it does not comprise digits. It may be the "$" that begins a line, the "*" that ends a line or perhaps an embedded ",".

Step 2. Of those bytes that are 0x30 or more, the upper nibble is the first digit to be made from this byte. The digit is decoded as upper nibble minus 3. An example of "C" code will look like this:

```
Something = (byte >> 4) -3;
```

If the lower nibble is 3 or more the same process is applied to the lower nibble.

```
if ( (byte & 0x0f) >= 3) {
  Something = (byte & 0x0f) -3;
  ......
  }
else {
  /* nothing to do no digit here */
  }
```

Applying this decoding process to every byte of the data that is 0x30 or more will produce an output of a string of digits.

Step 3. The next step is to insert the decimal points and commas (or spaces) as required. For this example, a decimal point needs to be inserted after 5 digits and, if required, commas after 10 and 12 digits.

$123456789012*
becomes
$12345.678,90,12*

The first number in this case is the field value (magnetometer reading). The second is a signal level indication. The third is the status value.

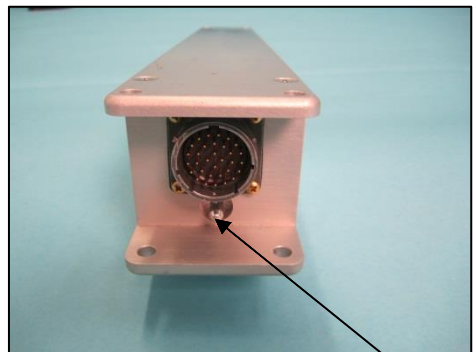
7.5 G-824A Warm-up Time

The sensor requires 5 to 15 minutes for warm-up. This time is required for the G-824A to stabilize and transmit valid field readings. This warm-up time depends on the ambient temperature at the sensor and can be monitored by using the Larmor signal level. The signal level will start out low (less than 2), rise to some number over 5 and then settle to a steady number between 2.5 and 5 (depending on sensor angle). Once this steady state signal level has been reached, the magnetometer is warmed up.

7.6 Power-up Initialization

On power up all counters initialize as counter #0 and begin to output data at the default data rate. This data will appear as commands to any subsequent counter and will cause a brief period of negotiation until each counter assumes its place in the daisy chain order. Thus there will be some garbled transmissions to the logging PC immediately upon power-up.

7.7 Hemisphere Locking Switch



Hemisphere Switch

On the G-824 electronics console there is a three position switch under the large circular I/O Interface connector (see picture at right). Normally the switch will be in the Center position. In this position the magnetometer is in the Auto hemisphere mode. This mode looks at the signal level which varies with orientation, and gets smaller as you approach the dead zone. At the edge of the dead zone where the signal level falls to near zero an internal circuit hunts for larmor signal by switching the hemisphere of operation back and forth. If it finds a signal it locks the hemisphere setting down until the signal approaches the dead zone and falls to near zero again. Thus if the sensor is rotated through its equatorial dead from one hemisphere to the other, the G-824 will start hunting as it enters the dead zone and automatically find and lock to the signal as the sensor emerges into the other hemisphere. [For a description of Hemisphere switching and dead zones see appendix A4 and section 3.0].

Occasionally this automatic hunting is not desirable. Perhaps the survey wants to skirt as close as possible to the dead without having the hunt mode come on prematurely. Or perhaps an powerful EM transmitter signal is going to quench the larmor signal while sensor will only be operating in only one hemisphere. In this case the hemisphere hunting circuitry could delay the reemergence of the larmor signal after the EM transmit pulse is gone. Therefore there are two other switch positions to lock the G-824 into only one hemisphere of operation (North or South).

Note that this is a mechanically locking switch to prevent accidental changes in switch position. To change the switch setting you must pull out the toggle bar first before changing the switch position.

If want to lock the hemisphere:

1) If the sensor is mounted vertically with the cable on top, then in the Earth's northern hemisphere you would set the switch to the right as shown in the picture above. In the Earth's southern hemisphere the switch would be set to the right.

2) If the sensor is mounted vertically with the cable down then the switch settings will be opposite to 1) above.

In practice it may be faster to just mount the sensor and set the switch left or right. If there is signal fine. If not just switch to the other hemisphere locked position.

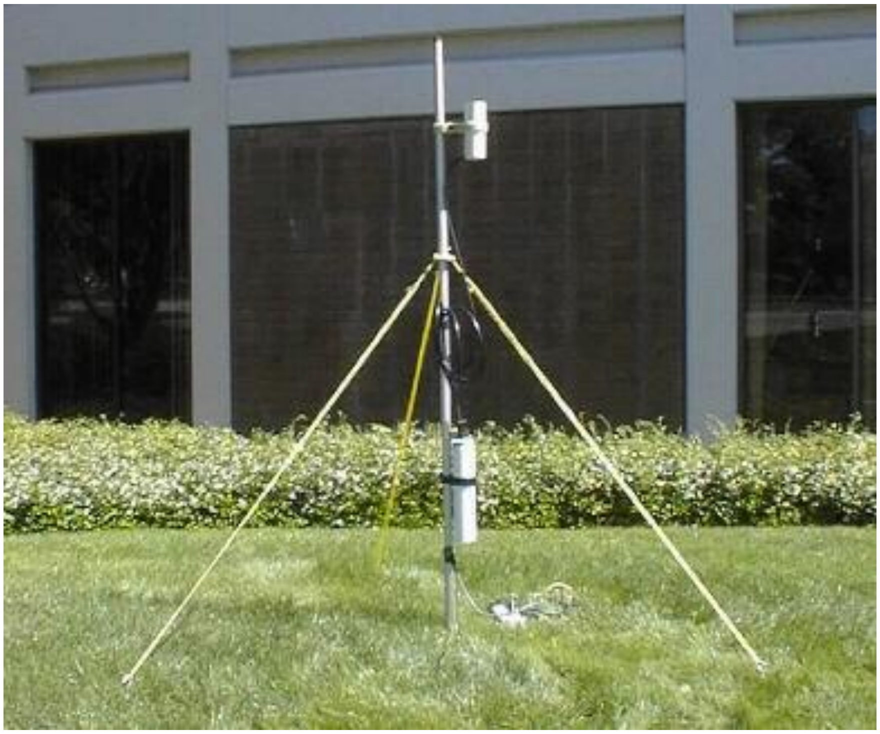
8.0 G-824B MAGNETOMETER

The model G-824B magnetometer is a variant of the G-824A intended for use as a high-performance base-station instrument. This model has the same dimensions and performance as the G-824A with the exception of its heading error. G-824B heading error is larger than the “A” sensors and not specified. As with the G-824A, the G-824B is shipped with a 25ft external signal/power interface cable, a power/data junction box, and an RS-232 data cable. These components are used to connect the magnetometer to the user’s 30VDC power source and logging computer.

When used as a base station, Julian date/time are available for recording and the standard sensitivities and measurement rates of the CM-321 counter apply. In this application the A/D converters installed in the CM-201 can be used to convert and transmit other analog signals (i.e., barometric altitude). Recording rates from once each 1 second to 100 times per second may be selected. Higher sample rates may be possible, but will depend on the number of transmitted characters, format, and baud rate.

The 25ft power/data cable included with G-824B will permit the logging computer to be located far enough from the sensor to avoid interference. Base-station data will also be more noise free if the sensor is positioned in a spot where the gradients are relative low. Such a spot may be located by casual surveying of the area selected for the base station site and identifying the spot with the most uniform field. Selecting this spot will also make a reoccupation of the spot easier (e.g. for base-station recordings used for block-leveling regional survey data).

We recommend a base-station installation that places the sensor approximately 5ft (1.5m) above the ground in order to reduce motion-induced noise. Motion noise will be proportional to both the amount of sensor motion and the size of the local gradient. Positioning the sensor off the ground will reduce the gradients arising for the soil or from outcrops. It is also important to provide a rigid support structure to keep wind induced motion to a minimum. Figure 7 shows a base station installation that uses a kit supplied by Geometrics for this purpose.



G-824B magnetometer installed using sensor staff sections as mast. Webbing guys re used to stabilize the mast. This installation provides a rigid, non-ferrous support for the sensor that presents minimal wind resistance.

Base Station Tripod

9.0 ACCESSORY SOFTWARE

9.1 Cesium Sensor Azimuth Program - CsAz

The CSAZ Windows™ program is available on our Magnetometer CD and from our FTP site at ftp://geom.geometrics.com/pub/mag/Software/ (see csaz-setup.exe). Please read the manual that is included with the program for complete instructions on how to use the CSAZ program for worldwide inclination and sensor orientation solutions.

APPENDIX A1. MODEL G-824A SPECIFICATIONS

OPERATING PRINCIPLE:	Self-oscillating split-beam Cesium Vapor (non-radioactive)
OPERATING RANGE:	20,000 to 100,000 nT
OPERATING ZONES:	The earth's field vector should be at an angle greater than 6º from the sensor's equator and greater than 6º away from the sensor's long axis. Automatic hemisphere switching
SENSITIVITY:	<0.0004 nT/√Hz rms. Typically 0.002 nT P-P at a 0.1 second sample rate (90% of all readings falling within the P-P envelope) using 824A SupremaC counter
HEADING ERROR:	<0.15 nT over entire 360º polar and equatorial spin
ABSOLUTE ACCURACY:	Better than 3 nT throughout range
OUTPUT:	Cycle of Larmor frequency = 3.498572 Hz/nT, RS-232 data at 9600 to 115200 baud, concatenated data streams from up to 6 sensors
MECHANICAL:	
SENSOR:	2.375" (60.32 mm) dia., 6.25" (158.75 mm) long, 12 oz (339 g) without cable, 24 oz (680 g) with cable
SENSOR ELECTRONICS:	2.5" (63.5 mm) dia., 11" (279.4 mm) long, 24 oz (680g)
CABLES:	
Sensor to electronics:	109" (2.77 m). Cable length in 40" (1.01 m) increments can be added or subtracted from the standard 109" length up to a maximum of 189".
Sensor Electronics to Counter:	Up to 220 ft (70 m)
OPERATING TEMPERATURE:	-30ºF to +122ºF (-35ºC to +50ºC)
STORAGE TEMPERATURE:	-48ºF to +158ºF (-45ºC to +70ºC)
ALTITUDE:	Up to 30,000 ft (9,000 m)
WATER TIGHT:	Sealed for up to 2 ft (0.9 m) water depth
POWER:	24 to 32 VDC, 0.75 amp at turn-on and 0.5 amp thereafter
ACCESSORIES:	
Standard:	Power/RS-232 multi-conductor cable (electronics to power/data junction box with 9 pin RS-232 connector and power lugs), lengths to be specified, spare O rings, operation manual and carrying case
Optional:	
Logging Software	MagLog (Logs GPS and Mag, shows track-plot, mag profile)
Accessories	Birds, Stingers, Wingtips, Avionics, GPS receivers

SPECIFICATIONS SUBJECT TO CHANGE WITHOUT NOTICE

APPENDIX A2. MODEL G-824B SPECIFICATIONS

OPERATING PRINCIPLE:	Self-oscillating split-beam Cesium Vapor (non-radioactive)
OPERATING RANGE:	20,000 to 100,000 nT
OPERATING ZONES:	The earth's field vector should be at an angle greater than 6º from the sensor's equator and greater than 6º away from the sensor's long axis. Automatic hemisphere switching.
SENSITIVITY	<0.0004 nT/√Hz rms. Typically 0.002 nT P-P at a 0.1 second sample rate (90% of all readings falling within the P-P envelope) using G-824 SupremaC Counter
HEADING ERROR:	Not specified on 824B
ABSOLUTE ACCURACY:	Better than 3 nT throughout range
OUTPUT:	Cycle of Larmor frequency = 3.498572 Hz/nT, RS-232 data at 9600 to 115200 baud, concatenated data streams from up to 6 sensors
MECHANICAL:	
SENSOR:	2.375" (60.32 mm) dia., 6.25" (158.75 mm) long, 12 oz (339g) without cable, 24 oz (680 g) with cable
SENSOR ELECTRONICS:	2.5" (63.5 mm) dia., 11" (279.4 mm) long, 29oz 822g)
CABLES:	
Sensor to electronics:	109" (2.77 m). Cable length in 40" (1.01 m) increments can be added or subtracted from the standard 109" length up to a maximum of 189".
Sensor Electronics to Counter:	Up to 220 ft (70 m)
OPERATING TEMPERATURE:	-30ºF to +122ºF (-35ºC to +50ºC)
STORAGE TEMPERATURE:	-48ºF to +158ºF (-45ºC to +70ºC)
ALTITUDE:	Up to 30,000 ft (9,000 m)
WATER TIGHT:	Sealed for up to 2 ft (0.9 m) water depth
POWER:	24 to 32 VDC, 0.75 amp at turn-on and 0.5 amp thereafter
ACCESSORIES:	
Standard:	Power/RS-232 multi-conductor cable (electronics to power/data junction box with 9 pin RS-232 connector and power lugs), lengths to be specified, spare O rings, operation manual and carrying case
Optional:	Birds, Stingers, Wingtips, Avionics, GPS receivers

SPECIFICATIONS SUBJECT TO CHANGE WITHOUT NOTICE

APPENDIX A3. SENSOR INSTALLATIONS

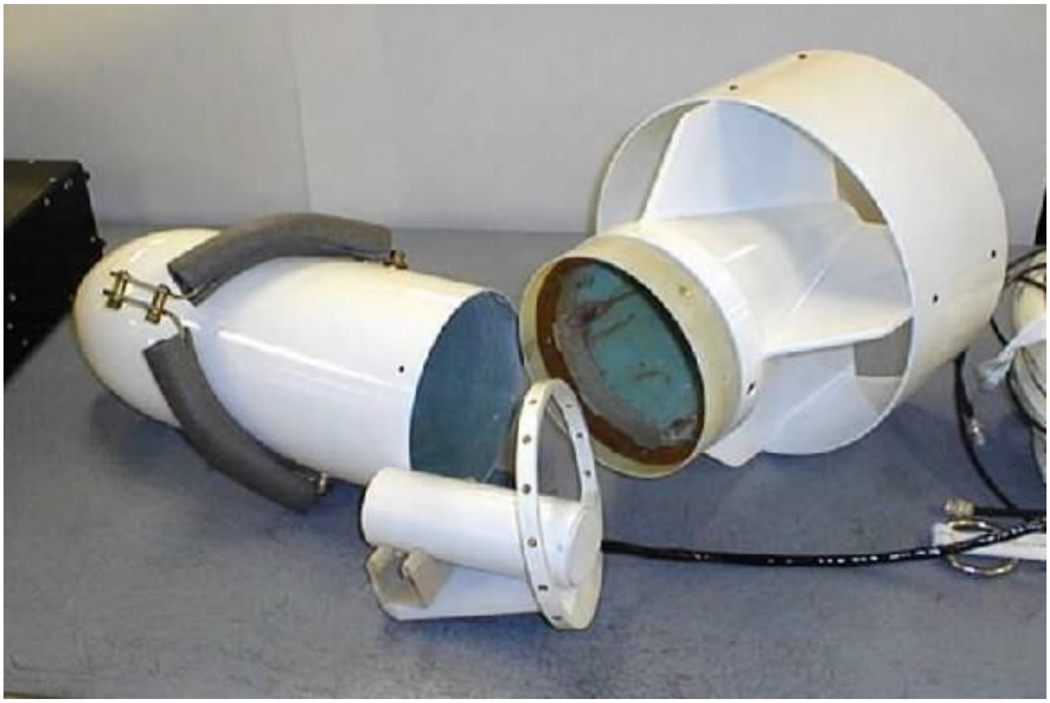


Figure A1. G-824A sensor and G-824A Bird components

Figure A2. Airborne Stinger showing sensor mount.

Figure A3. Aircraft fitted with stinger assembly

Figure A4. Aircraft fitted with horizontal transverse and longitudinal gradiometer using faired wingtips and stinger.

Figure A5. G-824A Boom installation on Ultra-lite autogyro.

Figure A6. Single sensor boom installation on Helicopter.

Figure A7. Multi-sensor (7) MTADS Helicopter installation for UXO survey.

Figure A8. Rack mount for airborne geophysical survey system

Figure A9. MTADS multi-sensor array for UXO survey applications.

Figure A10. Multi-sensor array on cart for UXO or archaeological surveying.

APPENDIX A4. CESIUM-VAPOR SENSOR THEORY

Note: The following section is provided for information purposes only. Understanding this theoretical discussion is not required for proper operation of the magnetometer.

For purposes of this discussion, the ambient magnetic field or earth's magnetic field is called H_0. A separate magnetic field generated by an AC signal applied to a coil inside the sensor is called H1. This coil is shown cross-section along with the other sensor components in Figure A11.

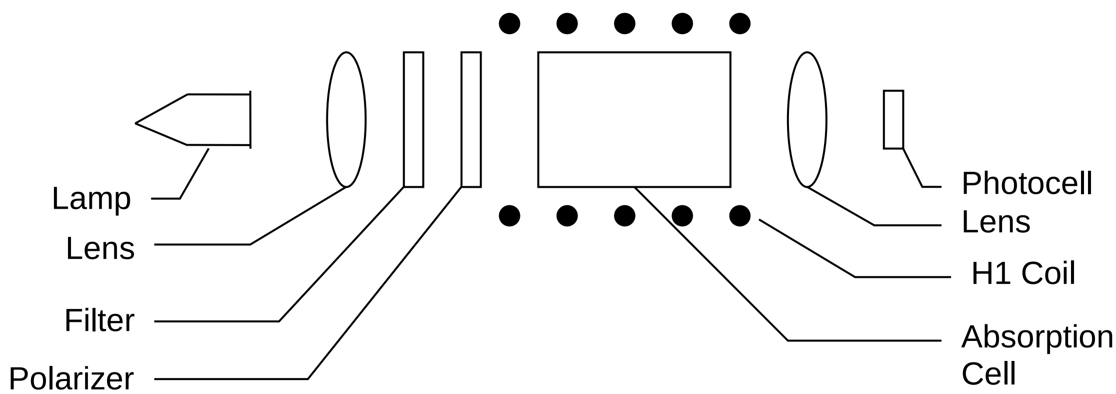


Figure A11. G-824A cesium-vapor

To initiate operation of the sensor, the lamp oscillator's RF power increases until the lamp strikes (plasma ignites and fluoresces). The lamp oscillator then reduces its power to produce the regulated amount of light. The heater warms the absorption cell until a Cesium vapor is formed. A lens bends the light from the lamp to parallel rays. The lamp produces many spectral lines but only one line in the infrared region is employed. All of the other light is blocked by a high grade optical filter.

The infrared line of interest is then passed through a split-circular polarizer. On one side of the polarizer the transmitted light has an electrostatic vector that advances with a right-handed rotation. For conceptual purposes, it can be said that all of the photons in this light have the same right-hand spin direction. The light transmitted through the other side of the split-circular polarizer produces light in which the vector advances with a left-handed rotation, therefore having the opposite spin. Both circular polarized light beams pass through the absorption cell. Because there is a buffer gas in the cell, the single cell can be considered as two separate cells, each having the opposite sense polarized light passed through it. Both light beams exit the cell and pass to a second lens. This lens focuses the light onto an infrared photo detector.

Because Cesium is an alkali metal, the outer most electron shell (orbit) has only one electron. It is the presence of this single electron that makes the Cesium atom well-suited for optical pumping and therefore magnetometry.

The Cesium atom has a **net magnetic dipole moment**. This net dipole moment, termed **F**, is the sum of the **nuclear dipole moment**, called **I**, and the **electron's angular momentum**, called **J**. In a Cesium atom:

I = 7/2
J = 1/2

and thus **F** can have two values depending on whether the electron's angular momentum adds to or subtracts from the nuclear dipole moment. Therefore, **F** can have the value of **3** or **4**. These values are called the hyperfine energy levels of the ground state of Cesium.

Normally the net dipole moments are randomly distributed about the direction (vector sum of the 3 axial components) of the ambient magnetic field (H_0). Any **misalignment** between the net atomic dipole moment and the ambient field vector causes the Cesium atom be at a higher energy level than if the vectors were aligned. These small differences are called **Zeeman splitting** of the base energy level.

The laws of quantum electrodynamics limit the inhabitable atomic magnetic dipole orientations and therefore the atomic excitation energy to several discreet levels: 9 levels for the **F=4** state and 7 levels for the **F=3** state. *It is this variation in electron energy level state that is measured to compute the ambient magnetic field strength.*

When a photon of the infrared light strikes a Cesium atom in the absorption cell, it may be captured and drive the atom from its present energy level to a higher energy level. To be absorbed the photon must not only have the exact energy of the Cesium band gap (therefore the narrow IR line) but must also have the correct spin orientation for that atom.

There is a high probability that the atom will immediately decay back to the initial energy level but its original orientation to the ambient field is lost and it assumes a random orientation. An atom that returns to the base level aligned such that it can absorb another photon, will be driven back to the higher state. Alternately, if the atom returns to the base level with an orientation that does not allow it to absorb an incoming photon, then it will remain at that level and in that orientation. Atoms will be repeatedly driven to the higher state until they happen to fall into the orientation that cannot absorb a photon. Consequently, the circularly polarized light will depopulate either the aligned or inverse aligned energy states depending on the orientation (spin) of light polarization. Remember that one side of the cell is right-hand polarized and the other left-hand polarized to minimize sensor rotational light shifts and subsequent heading errors.

Once most of the Cesium atoms have absorbed photons and are in a state that does not allow them to absorb another photon, the light absorption of the cell is greatly reduced, i.e., more light hits the photo detector. If an oscillating electromagnetic field of the correct radio frequency is introduced into the cell, the atoms will be driven back (depopulating the energy level) into an orientation that will allow them to absorb photons again. This frequency is called the Larmor frequency and is exactly proportional to the energy difference caused by the Zeeman splitting mentioned previously. This energy splitting is in turn directly proportional to the ambient magnetic field strength. The relationship between frequency and energy is given by:

$$E = f\hbar$$

Where:

E is the Zeeman energy difference

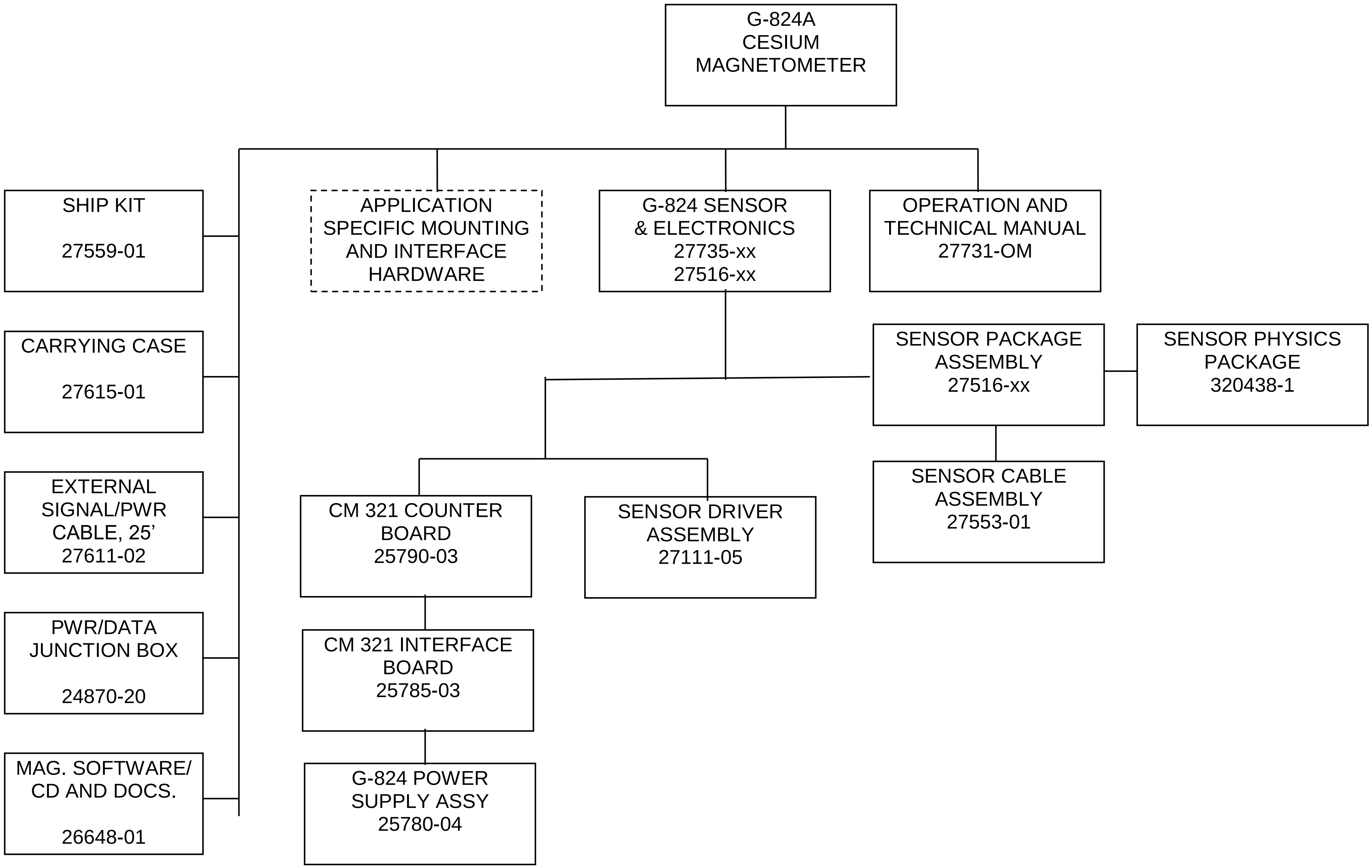
f is the frequency of the Larmor

$\hbar$ is Planck's constant

In Cesium this Larmor frequency is exactly 3.498572 times the ambient field measured in nano-teslas (gammas). In the G-824A this radio frequency field is generated by a coil, called the H1 coil that is wound around the tube holding the optical components. When the R.F. field is present the total light passing through the cell is reduced because atoms are in an energy state in which they can again absorb the infrared light.

There is a small variation in the atomic light absorption at the frequency of the applied H1 depopulation signal. This variation in light intensity appears on the photo-detector as a small AC signal (micro-volts). If this AC signal is amplified and shifted to the correct phase, it can be fed back to the H1 coil to produce a self sustaining oscillation. In practice simply connecting the 90° phase shifted and amplified signal to the H1 coil will cause the oscillation to spontaneously start. Reversing the direction of the earth field vector (H_0) through the sensor requires the drive to the H1 coil to be inverted to obtain oscillation.

APPENDIX A.6 G-824A GENERAL BLOCK DIAGRAM OF SYSTEM COMPONENTS



APPENDIX A.7 G-824B GENERAL BLOCK DIAGRAM OF SYSTEM COMPONENTS